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Alternative Building Technologies CT19

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Alternative Building Technologies for Low-Income Housing in Cape Town, South Africa

An Interactive Qualifying Project Report Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Abstract

Innovations in building materials are revolutionizing home-building, allowing homes to be constructed in a faster, cheaper, and more environmentally friendly manner. This project aimed to assist the City of Cape Town Department of Human Settlements (DHS) in implementing alternative building technologies in Breaking New Ground (BNG) housing projects. We interviewed BNG housing residents, DHS officials, and industry professionals, in addition to researching available alternative building technologies in South Africa. We identified areas in which BNG housing can be improved and how alternative materials can help the DHS better serve the needs of Cape Town's low-income population. Furthermore, we provided guidance for how these technologies can be successfully implemented by the DHS.

Executive Summary

BNG Development in Delft

BNG Construction in Atlantis

Purpose

In Cape Town, South Africa, thousands of families live in inadequate and informal housing conditions where their health and physical well-being is put at risk every day. Our sponsor, the City of Cape Town Department of Human Settlements (DHS), is working to provide low-income housing and build formal communities to better the lives of impoverished South Africans. The department views alternative building technologies (ABTs) as a potential way to increase the cost-efficiency, deliverability, and quality of government-built low-income housing. Our team's goal was to help the DHS explore different alternative building technologies and recommend ways in which these technologies could be implemented and used to improve low-income housing.

Background

The apartheid era had a tremendous impact on housing in South Africa and Cape Town. Apartheid restricted the property rights of black South Africans, segregated neighborhoods, and gave legal justification for the forcible removal of thousands of non-white South Africans from their homes. Although apartheid ended in 1994, it left a legacy of housing inequality and inadequacy across the country (Clark, 2019).

In 1994, the Reconstruction and Development Program (RDP) was created to alleviate poverty and social ailments by providing low-income housing to previously disadvantaged South Africans (RDP Housing, 2017). In 2004, the RDP was updated and renamed the Breaking New Ground (BNG) program to provide free housing to low-income South Africans (Breaking New Ground, 2004). However, with over 350,000 households awaiting BNG housing on the city's housing registry, the government struggles to satisfy the high demand for affordable housing.

While government-built housing often provides residents with improved living conditions,

residents still face a multitude of problems in low-income housing developments. Overcrowding, improper construction, and structural defects commonly have adverse effects on people's safety and health in these communities (Buys, 2013). These conditions leave many residents feeling dissatisfied with their home.

Alternative building technologies provide a wide range of benefits that could help improve the quality of BNG housing and better residents' lives. However, public resistance to ABTs exists because brick and mortar housing is the cultural norm in South Africa. Many low-income South Africans aspire to live in a brick and mortar house and expect their BNG house to be built with these conventional building materials (Aigbayboa, 2018). In addition, low-income communities can be resistant to ABTs because they perceive them to be of lesser quality and untrustworthy (Warrington, 2013).

Project Objectives

The goal of this project was to help the DHS improve the quality, safety, and cost-efficiency of BNG housing in Cape Town through the utilization of alternative building technologies. To achieve this goal, we focused on five objectives.

1. Evaluate safety conditions in select BNG housing developments in Cape Town
2. Determine cost feasibility of various alternative building technologies in comparison to conventional building methods
3. Assess residents' satisfaction with BNG housing
4. Determine public perceptions of implementing alternative building technologies
5. Identify suitable alternative building technologies for future Department of Human Settlements projects.

Methods

To complete these objectives, the team conducted semi-structured interviews with residents in four different BNG developments: Delft, Belhar, Fisantekraal, and Atlantis. BNG housing residents were asked a variety of questions with themes relating to satisfaction, safety, and public perceptions of building materials. This information was used to determine the current conditions of BNG housing and allowed the team to determine where alternative building technologies could be implemented to make improvements.

The team also conducted semi-structured interviews with various alternative building technologies suppliers and construction companies. These interviews focused on addressing the qualities of the technologies, public perceptions, and cost. The cost data was compiled to conduct a cost analysis between conventional and alternative building methods. Through these interviews we gained information about construction methods and the available alternative building technologies in South Africa. This helped us provide a more informative report to the DHS.

Outcomes

Finding 1: Most quality issues with BNG homes are not related to the building materials. BNG residents reported seven main maintenance issues with their BNG home: faulty windows, broken doors, leaky water faucets, leaky ceilings, cracks, mold, and faulty toilets. Of these seven issues,

Interviewing BNG resident in Delft

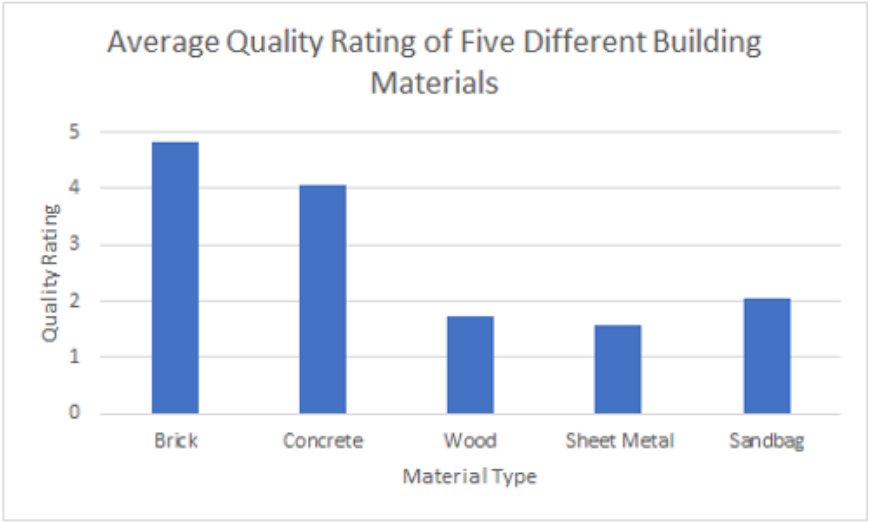
only the cracked walls and mold can potentially be attributed to the house's building technology and materials. Certain ABTs can help mitigate the occurrence of cracked walls and mold; however, the implementation of ABTs will not solve the other reported maintenance issues because these issues are not related to the houses' building materials.

Finding 2: Residents have concerns for their personal health and safety in BNG homes. Residents overwhelmingly identified ventilation as the key issue they thought the government could improve in future BNG housing. Residents reported that they and their family members had fallen ill in the past because of the lack of ventilation in their house. We also found that residents have concerns regarding crime and gangsterism in their communities because of South Africa's high crime rate. This is apparent from residents' desires for a closed yard and burglar bars to make them feel safer.

Finding 3: Negative public perceptions of ABTs stem from a poor understanding of what they are, but people's perceptions can improve with increased exposure. The team found that while many BNG beneficiaries distrust the quality of alternative building materials, there is a general lack of knowledge among BNG residents of what an alternative building material is. People are distrustful of non-conventional building materials because they have been primarily exposed to one type of housing (brick and mortar) and as a result are unaware of how ABTs can be used to construct quality housing. However, the team found that negative perceptions of ABTs can be overcome, and people become more accepting of ABTs once they physically experience a house built from alternative methods.

Finding 4: Before implementing ABTs the DHS must consider how ABTs may impact employment opportunities on BNG projects. The effect that ABTs have on labor creates dueling consequences for the DHS. The labor-saving qualities of ABTs conflict with the DHS's goal of utilizing labor-intensive construction methods to provide economic stimulus to the local community. However, ABTs are advantageous for the DHS because they offer simplified construction processes that reduce the need for specialized tradesmen allowing the DHS to employ more unskilled laborers. While ABTs may reduce the total number of people employed by a BNG project, they allow a greater percentage of the labor force to be comprised of unskilled laborers from the local community.

Finding 5: The current tendering process favors conventional building materials and makes it difficult for the DHS to implement ABTs in BNG developments. The tendering process was created to ensure that the DHS hires the most suitable candidate for the construction of BNG homes by opening the bidding process to anyone interested. We found that the current tendering process emphasizes three areas: supply chain, prior implementation of the proposed building technology, and cost of each housing unit. In all three of these categories, conventional building materials have an edge over the available alternatives, often causing the DHS to award tenders to bidders who use conventional building methods. The tendering process poses a major obstacle to the DHS if they wish to implement alternative building technologies in future BNG projects.



Graph from BNG resident interview data

Finding 6: Alternative block systems are the most feasible for the DHS to implement in future projects however they do not provide all the advantages that other ABTs can offer. Alternative blocks look like conventional concrete blocks; however, they are made from different composites that improve strength, reduce weight, and increase manufacturability. Even though alternative block systems do not provide all the advantages that other ABTs have to offer, they are easier for the DHS to implement because of previous experience working with them, positive public perceptions, and cheaper costs when compared to other ABTs. Despite these factors, the DHS should still consider whether other ABTs better address the DHS's long-term goals of improving the quality of housing and creating sustainable communities.

Recommendations

1. Reform the tendering process to de-emphasize cost and prioritize factors that more closely align with the DHS's long-term goals. We recommend that the BNG tendering process be reformed on the national level to de-emphasize the importance of cost and give greater credence to other important factors essential to building a development that will best serve beneficiaries. The scoring index used by the Bid Evaluation Committee should consider the quality, sustainability, and unique design advantages of every bid's proposed building method.

2. To improve public perceptions of ABTs, the DHS should engage in outreach efforts to inform BNG beneficiaries about ABTs. In order to make beneficiaries more receptive to ABTs the DHS needs to engage in multiple community outreach strategies. Initially, we suggest that the DHS present future beneficiaries with pamphlets outlining the ABT to be utilized in their community. Then information sessions for community members should be held in local community spaces giving residents a chance to learn more and ask questions. Finally, the DHS should consider building a model home and involving community members in the construction process so beneficiaries can better understand the material and see what a finished house looks like from that ABT.

3. Improve ventilation in future BNG homes to reduce health risks and improve residents' quality of life. The DHS should invest in alternative building technologies to improve ventilation because this is what residents wanted improved in future developments. ABTs can be used to reduce the cost to build BNG homes and free funds that can then be allocated to implement a ventilation system. Certain ABTs also offer the advantage of preventing moisture retention better than conventional concrete blocks.

4. Prioritize building BNG developments using alternative block systems in the immediate future. We recommend that the DHS prioritize building BNG developments using alternative block systems in order to achieve short term goals and begin the long process of changing public perceptions of ABTs. Building with alternative block systems will allow the DHS to build BNG projects at a lower cost compared to other forms of alternative building technologies. Additionally, alternative block systems employ unskilled labor, allowing the DHS to localize labor and provide economic stimulus in the immediate community where the BNG project is being built.

5. Partner with local non-governmental organizations and ABT companies to finance and build emergency housing for BNG beneficiaries. The DHS should partner with nonprofitable organizations and ABT companies to build emergency BNG housing using ATBs. The small-scale implementation of ABTs in emergency housing would serve the short-term goal of providing relief for BNG beneficiaries at no cost to the DHS. Simultaneously, such a partnership would also help the long-term goal of making BNG beneficiaries more comfortable with ABTs and provide the DHS with valuable experience on how to implement alternative technologies.

Conclusion

As the need for low-income housing in Cape Town continues to grow, the South African government will need to find new solutions to alleviate the city's housing shortage. The City of Cape Town DHS seeks to find and implement new building technologies in order to improve the delivery rate and quality of BNG housing. Our investigation into the conditions in BNG housing and exploration of alternative building technologies is intended to serve as a foundation that the DHS can use to build low-income housing utilizing alternative materials.

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Chapter 1: Introduction

Throughout the world there are an estimated 330 million families who live in substandard housing, defined as any "housing that poses a risk to the health and physical well-being of its occupants, neighbors, and visitors" (Avakian, 2019; Impact of Substandard Housing, 2018). Due to low incomes, many people live in informal settlements where they often lack proper sanitation and basic utilities (King, 2017). The housing inadequacies present in informal settlements have motivated governments and organizations alike to search for new low-income housing solutions to provide formal homes to disadvantaged communities (Making Affordable Housing, 2019).

In Cape Town, South Africa, there are thousands of families living in poverty without access to adequate housing (Human Settlements Review, 2010). Following the end of the apartheid era, the South African government tried to address the nation-wide housing shortage with the Reconstruction and Development Program (RDP), a program meant to improve peoples' social and economic conditions through government sponsored housing projects (Greyling, 2009). In 2004, the RDP was updated and renamed the Breaking New Ground (BNG) program (Breaking New Ground, 2004). While the government has been actively building low-income houses since 1994, it has not come close to meeting the demands for affordable housing in Cape Town. Currently, Cape Town's low-income housing communities suffer from overcrowding, crumbling infrastructure, poor sanitation, and safety hazards (Govender, 2011).

The City of Cape Town is actively trying to address these problems in new government sponsored housing developments. The government views alternative building technologies, the use of new building materials and construction techniques, as a potential way to build low-income housing faster and cheaper while providing beneficiaries with a better quality home. Alternative building technologies have been used in Cape Town's private home-building sector, but the government requires more research on how to implement alternative building technologies before using them in new low-income housing developments.

The goal of this project was to help the City of Cape Town Department of Human Settlements (DHS) improve the safety and cost-efficiency of government-built low-income housing in Cape Town through the implementation of alternative building technologies. This report includes a background chapter that discusses the history of housing inequality in Cape Town, outlines the challenges that low-income housing residents face in government housing, and explains conventional building practices in Cape Town. The methodology chapter describes how the team achieved the project goal and objectives by conducting research on alternative building technologies and interviewing relevant stakeholders. Finally, we discuss our findings and recommend the most feasible, cost-effective, building alternatives that the DHS can implement to improve the safety and quality of government-built low-income housing.

Chapter 2: Background Information

Currently, millions of people worldwide live in substandard housing conditions and this problem is expected to get worse. By 2025, it is estimated that the number of urban households occupying inadequate, unsafe, and crowded housing will rise to roughly 440 million (Avakian, 2019). The City of Cape Town, like many other cities, tries to address affordable housing through government housing programs for low-income citizens.

2.1 Historical Context of Housing Problems in Cape Town

The apartheid era in South Africa left a legacy of housing inequality and inadequacy in Cape Town and across the country (Clark, 2019). Apartheid was a series of policies that were aimed at disenfranchising black and coloured South Africans on the basis of race. In South Africa the term "black" refers to indigenous Africans, and "coloured" describes people of multi-ethnic decent (Pariona, 2019). The 1913 Native's Land Act designated less than 10% of South Africa's territory as black "reserves" (a.k.a. homelands) and prohibited black people from purchasing land outside these reserves (Cape Town the Segregated City, 2014). This greatly reduced black South Africans' ability to build and own houses because the majority of the population (black South Africans constitute over 70% of the population) was allowed property rights to less than 10% of the available land (Smith, 1992). Today, land distribution is still greatly impacted by the consequences of the Native's Land Act. A 2017 land audit by the South African government revealed that 72% of the country's arable land is owned by whites even though they account for less than 10% of the total population (Clark, 2019). By securing white ownership of a vast majority of the country's land, the Native's Land Act created lasting land inequality between the races despite its repeal over 25 years ago.

Apartheid not only restricted the property rights of black and coloured South Africans, but starting in the 1950s, it also forcibly removed many people off the land they were inhabiting. The Group Areas Act of 1950 divided cities and towns into segregated residential and business areas (Cape Town the Segregated City, 2014). From 1950 to the end of apartheid in 1994, millions of non-white South Africans were forcibly removed from areas that became classified as whites-only, having their houses, businesses, and schools destroyed by the government under the pretext of "slum clearance". Residents displaced from "reclassification" were forced to migrate onto land that had inadequate housing stock, forcing them to build informal dwellings (Cape Town the Segregated City, 2014). Informal dwellings are built outside of building codes and are usually located on land which occupants do not own (Informal Settlements, 2018). One of the most glaring examples of forced removals occurred in District Six, a racially diverse and economically vibrant community in Cape Town that was bulldozed after being designated a whites-only area in 1966 (Cape Town the Segregated City, 2014). Over 60,000 people were displaced and forced to relocate to informal settlements in Cape Flats, creating lasting housing instability in the community (Smith, 1992).

Since the end of apartheid in 1994 the South African government has been trying to address the inadequate and unstable housing conditions, brought on by apartheid, that millions of South Africans live in. In 1994, the Reconstruction and Development Program (RDP) was created to alleviate poverty and social ailments by providing low-income housing to previously disadvantaged South Africans (RDP Housing, 2017). In 2004, the RDP was updated and renamed the Breaking New Ground (BNG) program. The BNG program continued many of the

RDP's core principles, however it put a new emphasis on building complete communities, with roads, utility services, and businesses, rather than simply constructing housing (Breaking New Ground, 2004). Due to the similarities between the two programs, the terms "RDP housing" and "BNG housing" are often used interchangeably by the public. In this report, the term "RDP/BNG housing" will refer to government-built low-income housing unless specified otherwise. Even though, between 1994 and 2016, the government built nearly 3 million RDP/BNG houses for South African citizens, the government continues to struggle to meet the increasing demand for housing (RDP Housing, 2017).

2.1.1 Housing Shortage in Cape Town

In South Africa, 2.2 million families live in inadequate housing conditions that pose a risk to their health and well-being (Housing Deliver in South Africa, 2014). In Cape Town specifically, of the estimated 1.2 million households in the city, 320,000, live in overcrowded or informal housing conditions (McGaffin, 2018). On the City of Cape Town housing registry, a list of applicants who have applied to live in government funded housing, there is currently a backlog of roughly 350,000 households (Housing Delivery, 2014). Addressing this backlog in a 10-15 year period would require the construction of approximately 30,000 low-income homes per year. However, only 8,000 to 10,000 formal homes are being delivered annually by the government and private market (McGaffin, 2018). This is not nearly enough to bridge the housing gap that exists in the city and leaves over 20% of Cape Town residents living in informal dwellings (South Africa, 2014).

Another contributor to the housing shortage is that much of the existing formal housing in the city is unaffordable for most Cape Town residents. Formal housing consists of legal developments with planning oversight (Masum, 2014). Various surveys suggest that roughly 80% of the city's households make less than $1,320 (R20,000) per month (McGaffin, 2018). Based on the international standard that defines affordable housing as not exceeding 30% of a household's income, a household earning $1,320 (R20,000) per month can afford a home of about $33,000 (R500,000), or a monthly rent of about $330 (R5,000) (Avakian, 2019). In Cape Town though, the average home value is approximately $82,500 (R1,250,000) while the average rental rate in the Western Cape Province is roughly $590 (R8,800) (McGaffin, 2018; Seeff, 2018). This effectively prices out 80% of Cape Town's population from buying or renting a home on the private market and plays a large role in forcing an estimated 174,000 households to live in informal settlements around the city (Western Cape: Informal Settlements Status, 2013). However, those who do receive housing from the government in Cape Town face their own set of social and economic challenges.

2.1.2 Challenges in Low-Income Communities

A central problem in Cape Town's RDP/BNG housing developments is overcrowding. In RDP/BNG settlements, backyard dwellings, often referred to as shacks, are commonly constructed on the plot of a formal house. Research performed on four different RDP/BNG housing developments around Cape Town found that 94% of the subsidized housing plots had a backyard dwelling (Govender, 2011). Backyard dwellings increase a community's population density and place significant strain on the housing development's infrastructure. Overpopulation in a housing development can create unhealthy and unsafe living conditions for its residents.

In the year 2000, 13,368 deaths in South Africa were attributed to unsafe water, sanitation, and hygiene. This number accounted for 2.6% of all deaths in the country (Lewin,

2007). In a survey of four government subsidized housing developments in Cape Town, it was discovered that only 49% of houses had a toilet inside, and of these toilets only 41% of them were found to be in working condition (Govender, 2010). Many residents in the survey (92%) also reported that "they found it difficult to keep their home clean" (Govender, 2011, 340). These unsanitary conditions have resulted in high rates of diarrhea in low-income housing communities, as the same survey discovered that 38% of people had suffered from diarrhea in the two weeks preceding the survey (Govender, 2011).

In Cape Town's densely populated RDP/BNG housing developments, the risk of fire also threatens residents' safety. Densely built urban areas are particularly vulnerable to fire because of the lack of natural barriers (Moradi, 2016). Backyard dwellings are commonly built from flammable materials, like wood and plastic, and due to their close proximity to one another fires spread quickly (Shapurjee, 2013).

Figure 1: Before and after a fire in a low-income housing development (Walls, 2017)

Figure 1 shows a low-income community in Cape Town before and after a fire. The image on the left shows several large formal housing structures, surrounded by smaller shacks. After the fire (right image), the formal housing structures are still standing but all the shacks have burned down. Figure 1 highlights the fire hazard that backyard dwellings pose to low-income housing communities. Even though the fire does not appear to have done serious damage to the formal housing, it still threatened every community member's safety.

Additionally, low-income housing communities in Cape Town place low-income residents on the periphery of the city, farther away from jobs and services, because there is a lack of affordable land near the city center (Goebel, 2007). The lack of adequate land for urban development is one of the most important obstacles in creating low-income housing (Ugochukwu, 2015). Cape Town is experiencing a severe shortage of land as Patricia de Lille, a former Cape Town mayoral candidate, stated that the city is "running out of land for housing, particularly in the southern parts and Hout Bay" (Matheson, 2011, 31). Cape Town's geography plays a big role in this problem.

Figure 2: Image of Cape Town (Cape Town Mapping Project, 2013)

As shown in Figure 2, the opportunity for housing development on the eastern and western edges of the city are limited by mountain ranges, while the southeastern parts of the city have sandy soil making foundation construction difficult (Matheson, 2011). The scarcity of land has driven up land prices and has made Cape Town the most expensive city to build housing in South Africa (Head, 2019). In addition, the government is reluctant to use well located, more expensive land, near the Central Business District for low density subsidized housing (Becker, 2015). Officials at the DHS view alternative building technologies as a potential solution to this problem because new building materials could provide the government with a low-cost option for increasing the population density of future housing projects. However, more research is required before the DHS can implement alternative building technologies in new housing developments (S. Rono, personal communication, Oct 23, 2019). The desire in the low-income housing sector to save money has also led to substandard construction practices and defects in low-income housing (Goebel, 2007).

2.1.3 Construction Flaws in RDP/BNG Housing

The poor quality of low-income housing in South Africa is a symptom of a commodity culture where housing is viewed as a high-demand product that can be built for a low price to maximize profits (Zunguzane, 2012). In South Africa, RDP/BNG housing has a history of being poorly built and leaving many residents dissatisfied. In one study of an RDP/BNG housing community in Soweto, researchers reported that 55% of residents found the livability of their RDP/BNG house to be extremely unsatisfactory (Moolla, 2011). In another study, conducted in Alexandria, a township outside Gauteng (formerly Johannesburg), residents reported problems such as leaking water pipes (29.2%), poor structural stability (27.3%), and cracks in the walls (32.5%). Furthermore, roughly 71% of participants in the study said that they had experienced accidents or injuries due to defects in their homes (Zunguzane, 2012).

One of the main causes for the poor quality of low-income housing is contractors employing improper building techniques to save money on building materials and supplies (Buys, 2013). In one media report it was discovered that a contractor, trying to save on bricks and cement, had built 10 RDP/BNG houses without any foundations and had left holes in the

walls so large that people could see into the other rooms (Zunguzane, 2012). In a 2013 report on low-cost housing problems, Thuli Madonsela, the then Public Protector of South Africa, stated that she had received over 5,000 complaints about the quality of RDP/BNG housing, with some residents complaining of houses not having insulation and toilets (RDP Housing, 2017).

Even though there is a severe demand for housing in Cape Town, poor housing quality and unsafe conditions have driven many residents away from low-income housing developments. These challenges prompt many people to sell or rent out their government-provided home and move back to the informal settlements so they can be closer to their original community and economic activities (Goebel, 2007). The abandonment of government-provided homes shows that current low-income housing is not fulfilling people's needs and threatens to make low-income housing projects a waste of time and public resources in Cape Town.

2.2 Implementation of Low-Income Housing in Cape Town

Since the end of apartheid in 1994, there have been a multitude of policies, programs, and governmental agencies that were tasked with addressing low-income housing in South Africa. However, today, in the Cape Town context, the agency of importance is the Western Cape Department of Human Settlements. This agency is responsible for the implementation of low-income housing initiatives throughout Cape Town and the Western Cape Region.

2.2.1 Government-Sponsored Housing Policies

Like the rest of South Africa, the City of Cape Town takes two main approaches to low-income housing. This first approach is BNG housing where BNG housing is built by the South African government and is given to low-income families for free. These homes can only be owned, not rented, by beneficiaries. Families must first apply on the City of Cape Town housing registry to prove they qualify for BNG housing (Everything, 2017). The South African government deems families who earn a monthly salary of $235 (R3,500) or less as unable to provide for their own housing (Housing Delivery in South Africa). Over 50% of South African families are estimated to earn a monthly salary of $100 (R1,500) or less; therefore, over half of the country's population qualifies for BNG housing (Housing Delivery in South Africa, 2014).

Subsidized housing projects, on the other hand, operate through the partnership between the government and private business. Private developers build, maintain, and run affordable housing projects in exchange for the government offsetting some of the costs, and residents paying low rent (Ganiyu, 2017). This *quid*-pro-*quo* can take the form of granting tax credits or tax breaks, rent-assistance for tenants, or land trusts, which separate the cost of construction from the cost of acquiring land (Burch, 2014). These incentives are meant to encourage for-profit developers to construct low-income housing by making it a more profitable business. Subsidized housing follows a rent-based housing model, where tenants pay below-market rents to the private developers (South Africa, 2018). The City of Cape Town also has rental programs for low-income households for whom home ownership is unattainable and rental rates from private landlords are too expensive (Transport Development of Cape Town, 2018).

2.2.2 Conventional Building Materials

Conventional South African architecture and building techniques have strong British influences because of Britain's historical ties to the country. As a result, formal housing in South Africa is masonry intensive and the use of wood is uncommon (Maxwell, 2017). Most homes are constructed using a multi-thick layer of fired clay bricks which are then plastered over, inside

and out, with concrete stucco (Haselau, 2013). These techniques carry over into the construction of low-income houses where the most common building materials are bricks and concrete blocks. According to data from 2008, the walls of 78% of government-built houses in South Africa were made from bricks and nearly 20% were constructed from concrete blocks. The study reported that wood was not used in a single subsidized house and that other building techniques (corrugated iron walls and others) accounted for a combined usage rate of slightly over 2% (Marais, 2014). Informal dwellings are typically constructed with a frame made from timber poles or rectangular planks and insulated with timber boards or cardboard. The walls are usually made of timber or plastic sheets and have steel sheeting on the exterior (Walls, 2017).

2.2.3 Alternative Building Technologies and Perceptions

Peoples' perceptions of housing are largely shaped by social and cultural norms specific to different regions of the world (Aigbayboa, 2018). For a person to want to remain living in a house, their expectations and needs from the house must be met. The houses' building materials and construction process are a critical part of these expectations (Barnes, 2015). Living in a house constructed from brick and mortar is a standard that many low-income South Africans aspire to because the homes of wealthier South Africans are built with those materials. People are hesitant to live in low-income housing communities that are built from unconventional materials because they feel that alternative building technologies will brand them as poor and outcasts (Aigbayboa, 2018). Houses built using alternative technologies can look different from typical houses and as a result do not meet peoples' expectations. This can cause resistance to housing development proposals which incorporate alternative building systems and technologies (Mpakati-Gama, 2012). Furthermore, some South Africans associate certain building materials with poor housing and construction quality (Warrington, 2013). For example, wood is uncommon in formal houses but in informal settlements people regularly use the material to construct their shacks, and as a result people in Cape Town perceive wooden houses to be of low quality (Lategan, 2013). These perceptions surrounding alternative building technologies make the government feel compelled to build low-income houses using typical methods like brick and mortar because they believe that people will not want to live in them otherwise.

Despite negative perceptions, alternative building technologies have been successfully implemented in low-income communities in Cape Town. In 2009, EcoBEAM Technologies, a low-cost building construction company, built thirteen low-income houses in Monwabisi Park with the help of a Worcester Polytechnic Institute student team (Brown, 2009). The houses were built using EcoBEAM, an earthbag building system that constructs a house's walls out of sandbags. A metal lattice structure provides a framework for the house and sandbags are stacked inside, ultimately being covered in earthen plaster to finish the walls (Brown, 2009). Images of this technology can be seen in Figure 3.

Figure 3: Construction of Sandbag School in Cape Town (EcoBEAM, 2007)

Another alternative building technology that has been used in Cape Town is Moladi. As seen in Figure 4, Moladi is a construction technique where aerated mortar is poured into a mold made from reusable plastic panels (Moladi, 2019). The Moladi mortar is composed of local sand, cement, water, and moladiCHEM a water based chemical (Moladi, 2019).

Figure 4: Construction with Moladi Plastic Panels (Moladi, 2018)

In 24 hours, the plastic formwork is removed, and the house's outer shell is complete (Oh, 2015). Construction can be completed in only two days, much faster than houses built from conventional materials (Ncube, 2017). One of Moladi's biggest attributes is that low-income residents have generally taken to accepting the technology when used in their community (Ncube, 2017). In Durban, South Africa, a survey was conducted to assess residents' satisfaction with their new Moladi built homes. In the survey, 90% of residents stated that they liked the overall appearance of the Moladi house more than the conventionally built houses and that they were satisfied with their home (Ncube, 2017).

Despite having success in some low-income communities, across South Africa, the overall use of alternative building technologies in low-income housing is limited. Of the 2.9 million housing units that the South African government built between 1994 and 2009, the Human Settlements Review reported that only 17,000 of these houses were built using alternative building materials or innovative systems (Human Settlements Review, 2010). This constitutes only 0.06% of all housing units. One factor that has led to the homogeneity of low-income housing construction throughout South Africa and Cape Town, is that contractors prefer to use conventional building materials and technologies because they are familiar with them (Oguchukwu, 2015). While there are some who are open to the use of alternative building technologies, the Human Settlements Review stated that most government housing officials are unknowledgeable about how projects using alternative building technologies and materials are to be managed and implemented (Human Settlements Review, 2010). Furthermore, some

professionals in the construction industry avoid using alternative building technologies because they think these technologies are more expensive than conventional building methods (Leveraging, 2017). In South Africa, building materials account for roughly 38% of total housing costs and constitute the single largest financial input in housing construction (Bah, 2018). Therefore, the chosen building materials for a housing project play a major role in the project's financial feasibility. In Cape Town, the Department of Human Settlements views alternative building technologies as a potential way to improve the cost-efficiency of low-income housing construction.

2.3 City of Cape Town Department of Human Settlements

The City of Cape Town Department of Human Settlements (DHS) is the local division of the provincial Western Cape Department of Human Settlements. Created in 1994, the DHS was originally responsible for implementing RDP housing in and around Cape Town. The DHS currently builds low-income housing developments through the BNG program and has been doing so since the programs creation in 2004. The City of Cape Town Department of Human Settlements hopes to improve the safety and cost-efficiency of future BNG housing so it can better serve Cape Town's low-income community. Our team's role was to help the DHS gather resident feedback and explore the use of alternative building technologies to make future projects more cost-effective and safer for future residents. In the next chapter we outline our methods for achieving this goal.

Chapter 3: Methodology

The goal of this project was to help the City of Cape Town Department of Human Settlements improve the quality, safety, and cost-efficiency of Breaking New Ground (BNG) housing in Cape Town through the utilization of alternative building technologies. To achieve this goal, we focused on five objectives described below.

1. Evaluate safety conditions in select BNG housing developments in Cape Town
2. Determine cost feasibility of various alternative building technologies in comparison to conventional building methods
3. Asses residents' satisfaction with BNG housing
4. Determine public perceptions of implementing alternative building technologies
5. Identify suitable alternative building technologies for future Department of Human Settlements projects

This section discusses the methods we used to accomplish each objective. We explain how the group conducted each method and how the method helped us achieve our research goals.

3.1 Objective 1: Evaluate Safety Conditions in BNG Housing

To evaluate the safety conditions in BNG housing, the team conducted semi-structured interviews in four different BNG developments in Cape Town: Delft, Belhar, Fisantekraal, and Atlantis. DHS officials facilitated the interviews by introducing the team to interviewees and asking if they would be willing to participate in the team's interview. One team member had an observation note sheet (Appendix D) where they recorded observations about the house's exterior and interior conditions. When invited into the house, the team walked around the inside of the house before the interview and made observations about the house's condition and potential safety hazards. We recorded important observations, such as exposed wires, mold, and cracked walls.

Whenever possible the team interviewed the homeowner. However, in some cases the official homeowner was not home, so we interviewed an available adult who lived in the house. The team began the interview by asking residents a series of questions about safety conditions in their home. The interviews consisted of a mix of close-ended and open-ended questions. Close-ended questions were used to gather information about fire hazards and potential injuries suffered due to house defects. The team asked how safe residents felt in their home and what aspects of their home made them feel safe through open-ended questions. This line of questioning helped the team gather information about safety conditions through interviewee's stories and personal experiences. The full list of questions can be found in Appendix A. During the interview, one team member asked the prepared questions, while another took notes. However, when necessary, the note-taker frequently asked additional questions to further conversation. The data collected was later compiled in an Excel spread sheet where residents' responses were broken-down by question. In total we conducted 30 interviews across the four BNG developments, seven of which required a translator for Afrikaans and Xhosa. However, we only analyzed 24 of the interviews for safety hazards because several of the interviewees had moved into their home a few days before the interview. We analyzed the responses from all interviewees who had been living in their house for over four months and excluded the rest

because the newer houses were unlikely to have defects or deteriorating conditions causing safety hazards.

Evaluating safety hazards in BNG housing allowed the team to search for alternative building technologies that could appropriately address common problems. Combining both direct observations and responses from residents allowed the team to make a well-rounded evaluation of the safety conditions in BNG housing developments.

3.2 Objective 2: Determine Cost Feasibility of Alternative Building Technologies

The Department of Human Settlements provided financial records of previous BNG projects that outlined the costs for earthworks, brickwork, roof structure, labor, plumbing, electrical, and more for the three different types of BNG houses. Furthermore, the financial records provided data for a comparative analysis between the financial costs for BNG housing and alternative technologies.

The team reached out by email to various alternative building technology companies to request phone interviews to obtain information regarding alternative technologies. Phone interviews were conducted with the following companies: Moladi, EcoBEAM, PWP Architects, Ikhaya Futurehouse, Klevabrick, Amor, and Trumod. One interviewer primarily asked the questions, and the remaining team members recorded notes. The interviewer asked questions specifically tailored to help the team identify a building technologies' cost efficiency. The specific line of questioning was aimed at the material cost, speed of construction, and production capabilities. The full list of questions can be found in Appendix C.

Analyzing the cost-efficiency of various alternative building technologies allowed the team to provide a more informed recommendation for the DHS. It was critical that the team be able to show the DHS a financial comparison between their current building costs and the costs of using a new technology.

3.3 Objective 3: Assess Residents' Satisfaction with BNG Housing

In the same interview sessions from objective 1, the team conducted semi-structured interviews with residents of BNG housing to assess residents' satisfaction with their BNG house. We asked residents to rate their overall satisfaction with their home on a scale of 1 to 5. After receiving an answer from the residents, we asked them to explain why they choose their rating. This line of questioning gave us general insight into how residents felt about their home. The remaining satisfaction inquiry was a mix of close-ended and open-ended questions. Close-ended questions targeted specific information such as, how long they lived in the home and if they liked the house's building materials. Open-ended questions allowed residents to share their own thoughts and discuss what was important to them. These included prompts such as: explain how your living conditions have improved since moving into your BNG home; describe the quality of construction for your home; and how do you think the government could improve future BNG homes. All the specific questions asked to the residents can be found in Appendix A. The residents' responses were compiled in the same Excel spread sheet from objective 1, however we analyzed the data collected in Delft, Belhar, and Atlantis separately from the data collected in Fisantekraal. This was done because the interviewees in Delft, Belhar, and Atlantis lived in BNG housing constructed from conventional building materials (concrete blocks), while in Fisantekraal the BNG housing development was built from an alternative building block (polystyrene-cement block). The team wanted to see how residents' satisfaction compared across the different building methods.

Assessing residents' satisfaction with current BNG housing was a key objective for the project because it provided insight into what residents liked and disliked about their BNG house. With this information, the team could focus its research on alterative building technologies that could help alleviate the housing deficiencies that impact residents the most.

3.4 Objective 4: Determine Public Perceptions of Alternative Building Technologies

In a continuation of the interview session with BNG housing residents from objective 1 and 3, the team asked questions regarding residents' perceptions of different building materials and technologies. We included this line of questioning in the BNG resident interviews because the team wanted to understand the acceptance of alternative building technologies among Cape Town's low-income population. The team verbally listed examples of different building materials (brick, concrete blocks, wood, sand, metal) for the interviewees and asked them to rate the quality of these materials on a scale from one to five. We also asked interviewees whether they would consider living in a house built from these materials or any other alternative building material. The full list of questions can be found in Appendix A. This line of questioning was conducted in all four BNG developments, however, in Fisantekraal we modified our interview questions regarding perceptions of alternative materials.

In Fisantekraal we interviewed residents who lived in BNG housing built from an alternative building material. We asked these residents different questions about their perceptions of alternative building technologies than those in Appendix A because we wanted to collect data on whether living in a house built from an alternative building material changed residents' perceptions. These questions can be found in Appendix A.1. The data collected from these interviews was later transcribed in the same Excel spread sheet used in objective 1 and 3.

In the same phone interviews with alternative building technology companies from objective 2, we asked interviewees how public perceptions of alternative building technologies affect their work. We also asked interviewees if their experience working in South Africa had taught them any techniques for changing negative perceptions of alternative building technologies among the public. This information helped the team formulate our recommendations to the DHS for how they could successfully gain public support for the implementation of alternative building technologies in BNG housing. The interview questions can be found in Appendix C.

Determining public perceptions of alternative building technologies was a crucial part of the project. Alternative building technologies can only be implemented successfully if they have the community's support. The team needed to learn how acceptable new building materials were among low-income residents and whether more work was required to change public perceptions before alternative building technologies could be implemented in BNG housing.

3.5 Objective 5: Identify Suitable Alternative Building Technologies for BNG Housing

Before proposing alternative building technologies to the DHS, it was necessary to research the available alternative building technologies in South Africa that could help improve the safety and cost-effectiveness of BNG projects in Cape Town. In the same interview session from objective 2 and 4, the team conducted phone interviews with various companies that either supply alternative building materials, build using alternative technologies, or both. During the interview, the team asked questions about the implementation process, benefits and limitations, and technical and social challenges they face when implementing their technology. One team member asked the prepared interview questions (Appendix C) while the rest of the team took

notes. As the conversation developed, and new topics were discussed, the rest of the team asked relevant questions to further discussion.

We also needed to determine which of these new building techniques were the most feasible for the DHS to implement. We conducted informal interviews with two DHS employees: Duke Gumede, DHS Program Manager, and Simphiwe Rono, a DHS technician. Through these interviews we gathered information on how the DHS currently implements BNG projects and what needs the DHS would like a new building technology to satisfy. We also asked questions about the political and social elements of BNG projects and how this could impact the adoption of alternative building technologies in future projects. The full list of questions can be found in Appendix B.

The information gathered in these interviews was used to create a resource guide describing all the alternative building technologies the team encountered. The resource guide included images, costs, advantages, and disadvantages of all the technologies. This guide was given to the DHS to inform them about various alternative building technologies.

Chapter 4: Research Findings

In this chapter we present six findings from our research that provide insight into the process of implementing alternative building technologies in future BNG projects. The findings synthesize information we learned through interviews, direct observations, and online research of alternative building technology companies in order to make specific recommendations to the DHS in Chapter 5.

The City of Cape Town Department of Human Settlements (DHS) designs and builds low-income housing developments in the Cape Town region. After the end of apartheid, the Reconstruction and Development Program (RDP) was created to provide housing to millions of low-income South Africans for free. In 2004, in an attempt to improve the quality of government housing and promote community development, the Reconstruction and Development Program was replaced by the Breaking New Ground (BNG) policy. The new policy increased the size of government-built housing from 30 to 40 squared meters and reduced the area of each individual plot to increase densification. The BNG strategy places an increased emphasis on building whole communities instead of simply building homes and continues to provide beneficiaries with free low-cost housing.

Today, the DHS hopes to use alternative building technologies (ABTs) to improve both the delivery and quality of BNG housing in Cape Town. While the DHS has made strides towards making alternative building materials more prevalent in the construction of BNG housing, the DHS has never implemented ABTs on their own. Today, only BNG projects built on private land by private developers have used ABTs. Consequently, the DHS is eager to gather information on new building alternatives and learn how they can implement them themselves.

The six findings from our research discuss the complex relationships between building materials, BNG beneficiaries, and the DHS. Understanding these relationships was critical to making our recommendations in the following chapter.

Finding 1: Most quality issues with BNG homes are not related to the building materials.

According to Duke Gumede, Program Manager of District North in the City of Cape Town DHS, low-income housing built through the RDP was notorious for being poorly built and has given government-built low-income housing a bad reputation in South Africa (D. Gumede, Personal Interview, Oct. 30, 2019). The DHS hopes that the new BNG policy can change this reputation by providing beneficiaries with quality housing and sees alternative building technologies as a potential aid to achieving this goal. While conducting interviews in BNG developments in Cape Town, the team asked residents whether they had experienced any maintenance problems with their homes. From these interviews, and with observations recorded on our observation note sheet (Appendix D), the team found that the two most prevalent maintenance issues in BNG homes were cracked walls and leaking water faucets. Figure 5 shows the seven types of maintenance problems that the team observed and BNG beneficiaries reported, as well as the number of times these problems were found. The team recognizes that these maintenance issues may have occurred due to normal wear-and-tear from resident use, and not from improper construction. However, it is still important for the DHS to know the maintenance problems that BNG beneficiaries experience. Additionally, of the thirty BNG beneficiaries we interviewed, only one reported having a serious structural problem with their house, as the interviewee claimed that strong wind causes the ceiling to bend and move.

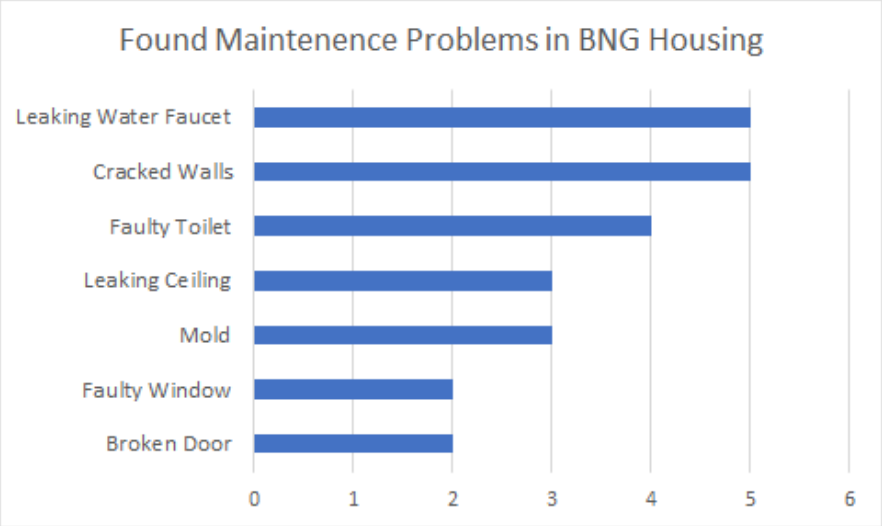

Figure 5: This graph shows seven different maintenance problems in BNG homes and the total number of instances in which the team observed these problems or BNG beneficiaries reported them.

The team found that of the seven types of maintenance issues that BNG beneficiaries reported, only the cracked walls and mold can potentially be attributed to the house's building technology and materials. Cracks could have formed because of poor plaster work, but they can also be caused by a variety of flawed construction processes such as a poor foundation. It should be noted that the team was unable to thoroughly inspect the houses, so the true cause of the cracks is unknown. Nonetheless, superficial cracking can be mitigated by using building technologies that do not use plaster. In the following finding (Finding 2) we will go into more detail about the occurrence of mold and ventilation issues in BNG homes. The implementation of ABTs will not solve the other reported maintenance issues because these issues are not related to the houses' building materials. For example, in the case of the structurally unstable ceiling, we found through interviews with ABT companies that alternative materials do not impact roof and ceiling construction, so these issues must be addressed with better construction practices.

Finding 2: Residents have concerns for their personal health and safety in BNG homes.

While conducting interviews in BNG developments, the team discovered that residents have concerns regarding their personal health and safety. As seen in Figure 6, when residents were asked how they thought the government could improve BNG housing, respondents overwhelmingly identified ventilation as the key issue they thought the government could improve in future BNG housing. Five residents reported that they and family members had fallen ill in the past because of the lack of ventilation in their house and three reported the occurrence of mold. Interviewees said that excess moisture trapped in the house caused them to develop breathing problems and experience sore throats. Currently, BNG housing is built using a waterproofing membrane under the floor slab and external walls, which mitigates moisture migration into the structure of the home. External walls are also painted with two coats of waterproof acrylic paint (JS Associates Architects & Urban Designers, 2015). While this prevents moisture from getting into the house, it also stops moisture from exiting and can create a vapor barrier that traps moisture from cooking, breathing, and other sources inside (Trechsel,

1994). This could be the cause of the mold that residents reported in Finding 1. As a result, BNG residents are concerned about the effects BNG houses are having on their personal health and want improved ventilation to be prioritized in future developments. Furthermore, the team found that DHS officials are aware of these ventilation issues because multiple officials expressed concerns over mold and musty smells developing in the houses, as a result of poor air flow (S. Rono, Personal Interview, Oct. 23, 2019).

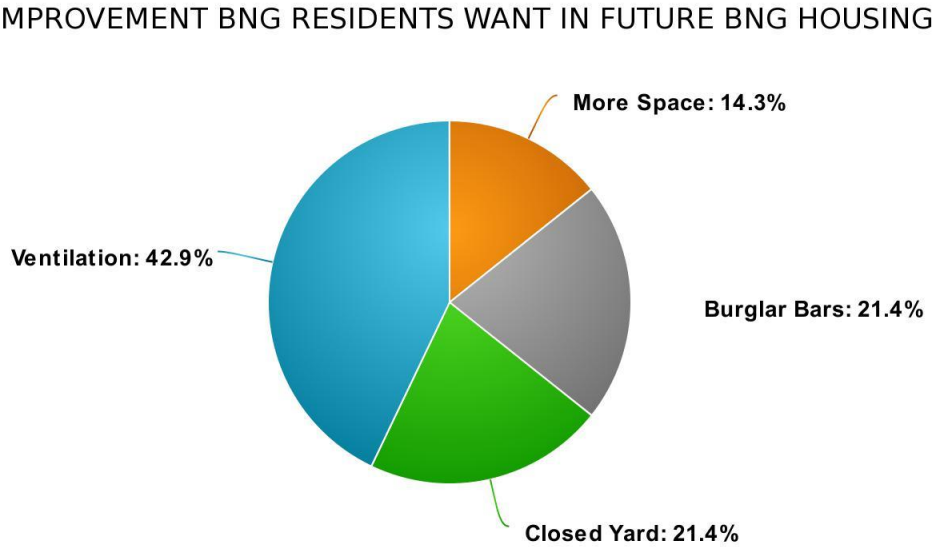

Figure 6: This graph shows improvements that BNG beneficiaries would like to see in future BNG developments.

A simple way to improve ventilation would be to keep windows and doors open so air can flow through the house. However, the team believes that BNG residents will be reluctant to do this over safety concerns, given South Africa's high crime rates. Overall, 70% of residents said they felt safe in their BNG home; however, nine residents said that they wanted burglar bars and a fenced yard to be safe from crime and gangsterism. As seen in Figure 4.2, this was the second most recommended improvement that residents would like in future BNG developments. All the residents that wanted burglar bars and a fenced yard said they do not feel safe enough to leave their windows and doors open unattended. Another possible solution is to insert perforated concrete blocks into the walls of the house which would allow air to flow in and out of the house.

Air quality could also be improved in BNG housing by the adoption of ABTs that prevent moisture retention unlike concrete blocks (B. Lewis, Phone Interview, Oct. 28, 2019). The ABT resource guide in Appendix E goes into more detail on which specific building systems provide better ventilation and prevent moisture retention. Unfortunately, ABTs cannot directly address the concerns that residents expressed about neighborhood safety; however, if the DHS implements ABTs that are cheaper than conventional building materials, thus reducing the cost of construction, more money may be available so the DHS can afford to provide beneficiaries with a closed yard and burglar bars.

It is important to recognize that the maintenance problems that people reported in Finding 1 do not mirror the improvements that residents said they want. When we asked residents how BNG housing could be improved in the future, respondents never directly referenced the maintenance problems from Finding 1. The only maintenance issue that relates to future

improvements is the problem of mold. This represents a noticeable contradiction in our data because it would be most logical to assume that people would want maintenance issues to be improved in future BNG developments. An explanation for this could be that because residents view ventilation, closed yards, and burglar bars as having an impact on someone's health and safety, they prioritize these improvements over maintenance issues, like cracked walls and leaking faucets that might be viewed as aesthetical concerns and problems of convenience. It is also possible that residents want health and safety improvements because they have come to accept maintenance problems as an unfortunate reality of BNG housing that is unavoidable. However, this is all conjecture and the team does not have solid evidence to support these claims.

Finding 3: Negative public perceptions of ABTs stem from a poor understanding of what they are, but people's perceptions can improve with increased exposure.

The successful implementation of ABTs in BNG housing will ultimately be determined by whether residents accept ABTs as a viable and quality product. The team found that while many BNG beneficiaries distrust the quality of alternative building materials, there is a general low level of knowledge among BNG residents of what an alternative building material is. As shown in Figure 7, when the team asked residents to rate the quality of different building materials on a scale from one-to-five, with five being the best and one being the worst, brick and concrete were constantly given higher ratings, with interviewees commonly saying that the other materials were weaker and inferior compared to their conventional counterparts. However, when we asked residents if they were familiar with the term "alternative building material" and if they knew of any examples, 75% of respondents answered in the negative. Mr. Gumede explained that many low-income South Africans aspire to live in brick and mortar houses because many upper- and middle-class South Africans reside in homes built from this material (D. Gumede, Personal Interview, Oct. 30, 2019). People are distrustful of non-conventional building materials because they have been primarily exposed to one type of housing (brick and mortar) and as a result are unaware of how ABTs can be used to construct quality housing. This is why nearly 80% of respondents reported that their ideal house would be constructed from brick or concrete block.

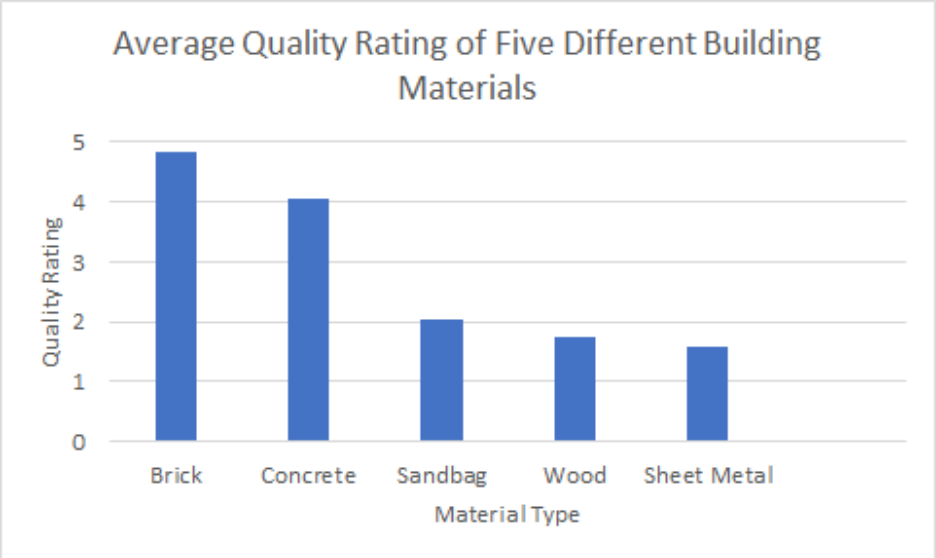

Figure 7: This graph shows the average quality ratings that BNG housing residents gave to five different building materials.

However, the team found that negative perceptions of ABTs can be overcome, and people become more accepting of ABTs once they physically experience a house built from alternative methods. In Fisantekraal, we conducted interviews in a BNG development built from an alternative block system (cement-polystyrene block), and asked interviewees how they thought the quality of the alternative block compared to conventional concrete blocks. As discussed before, across all interviewees there was a strong preference for conventional building materials, however, nearly 60% of respondents from Fisantekraal said the cement-polystyrene block was of better or same quality compared to conventional counterparts. Even though this data only shows BNG beneficiaries' perceptions of one type of ABT, and thus cannot be extrapolated to all ABTs, additional information from interviews conducted with ABT companies support our finding that people become more accepting of ABTs once they physically experience them. Both Hennie Botes, CEO of Moladi, and Barry Lewis, a collaborator with EcoBEAM, told similar stories of working with low-income communities who initially expressed resistance to their respective alternative building technologies. Nonetheless, after witnessing the construction process and experiencing the finished house, community members overwhelmingly approved of the product (B. Lewis, Phone Interview, Oct. 28, 2019; H. Botes, Phone Interview, Nov. 6, 2019). The team was unable to interview members living in these communities so these stories have a level of bias that should be considered. Regardless, the team is confident that the DHS can overcome negative perceptions and show BNG beneficiaries the quality of ABT constructed houses.

Finding 4: Before implementing ABTs the DHS must consider how ABTs may impact employment opportunities on BNG projects.

Building low-income housing is not the sole purpose of the BNG program. Mr. Gumede explained that BNG projects also function as an economic stimulus program because they provide employment to local workers. Low-income communities have high levels of unemployment and a large untrained labor pool. Mr. Gumede continued by saying that the DHS wants to hire more untrained labor and prefers labor intensive construction methods because it provides more employment opportunities for community members and injects more of the project's funds directly into the local economy (D. Gumede, Personal Interview, Nov. 6, 2019). The team found that the inclusion of the immediate community as part of the project's workforce is an essential part of BNG projects. Before implementing ABTs, it is important to consider their potential impact on labor.

Alternative building technologies primarily impact labor in two ways. Firstly, they reduce labor. Many ABT companies advertise their products as requiring less labor than conventional building methods. Of the thirteen ABT companies we researched, nine advertise on their websites, the reduction of labor as a major benefit of their technology. Even though the team could not verify the validity of all these claims, it highlights that reducing labor is at the forefront of the ABT industry. These labor-saving qualities conflict with the DHS's goal of utilizing labor intensive construction methods to increase employment. Secondly, many ABTs eliminate the need for specialized tradesmen by simplifying the construction process and create employment opportunities for unskilled laborers. Since BNG projects are built in communities with a large unskilled labor pool, implementing ABTs would allow the DHS to employ more people directly from the local community. This is advantageous for the DHS because it means more of the project's funds will go into the local economy. Table 1 compares the workforce required to implement five different categories of ABTs. While conventional brick and mortar construction

requires bricklayers, masons, and plasterers, Table 1 shows that ABTs require fewer of these trades and in some cases eliminates the need for them entirely. While ABTs may reduce the total number of people employed by a BNG project, they allow a greater percentage of the labor force to be comprised of unskilled laborers from the local community, which helps achieve one of the DHS's goals. Before implementing ABTs the DHS will need to consider how this trade-off effects the broader economic goals of the BNG program.

Table 1: Labor comparison of different ABTs

ABT	Sandbag	Structurally Insulated Panels	Alternative Block Systems	Moladi	Cross Laminated Timber
Supplier	EcoBEAM and EcoBuilders	Ikhaya Future House, Trumod, UFCC	Klevabrick, FinnBuilder, Rambrick, Selcrete	Moladi Building Communities	HWZ International Wood Solutions
Where does manufacturing occur?	Onsite	Factory	Factory and onsite	Onsite	Factory
Utilized labor force	Unskilled	Unskilled	Unskilled	Unskilled	Skilled
Need for bricklayer?	No	No	Yes	No	No
Need for mason?	No	No	No	No	No
Need for plasterer?	Yes	Yes	Sometimes	No	No
Suppliers that offer training	EcoBEAM	Trumod	Klevabrick, FinnBuilder, Rambrick	Moladi Building Communities	NA

Based on conversations with DHS officials, the team believes the most viable alternative building technologies for BNG projects increase the localization of labor at the construction site, increasing the number of jobs in the community and providing training and skills. Cross laminated timber is not advantageous to the DHS because it requires skilled labor and is manufactured in a factory. Structurally insulated panels (SIPs) combines components of conventional buildings into a singular modular piece with outer and inner wall surfaces sandwiching an insulating layer. Although SIPs are designed to take advantage of unskilled labor, they dramatically reduce the overall labor needed for construction (J. Scherman, Phone Interview, Oct. 29, 2019). Similarly, alternative block systems, sandbag housing, and Moladi also utilize unskilled labor for construction. A major difference is that these technologies can involve unskilled laborers in the onsite production of building materials (mixing concrete, forming blocks, and pouring sandbags). SIPs are manufactured in a centralized location (D. Kretzmann, Phone Interview, Nov 14, 2019). Alternative block systems, sandbag housing, and Moladi are more beneficial to the DHS than SIPs because they increase the localization of labor and employ unskilled labor.

Finding 5: The current tendering process favors conventional building materials and makes it difficult for the DHS to implement ABTs in BNG developments.

For the DHS to begin a new BNG housing development, the project must first go to tender. Mr. Gumede explained that tendering is a bureaucratic process in which contractors and developers bid for the right to construct an upcoming BNG project. Every tender must comply with South African building regulations and the DHS reviews the tenders to decide who to hire. Figure 8 shows the different steps in the tendering process. Once the tender is awarded the DHS can then begin working with the hired contractor or developer to build the project. The tendering process was created to ensure that the DHS hires the most suitable party by opening the bidding process to anyone interested. From our discussions with Mr. Gumede, we found that the current tendering process emphasizes three areas: supply chain, prior implementation of the proposed building technology, and cost of each housing unit. In all three of these categories, conventional building materials have an edge over the available alternatives, often causing the DHS to award tenders to bidders who use conventional building methods.

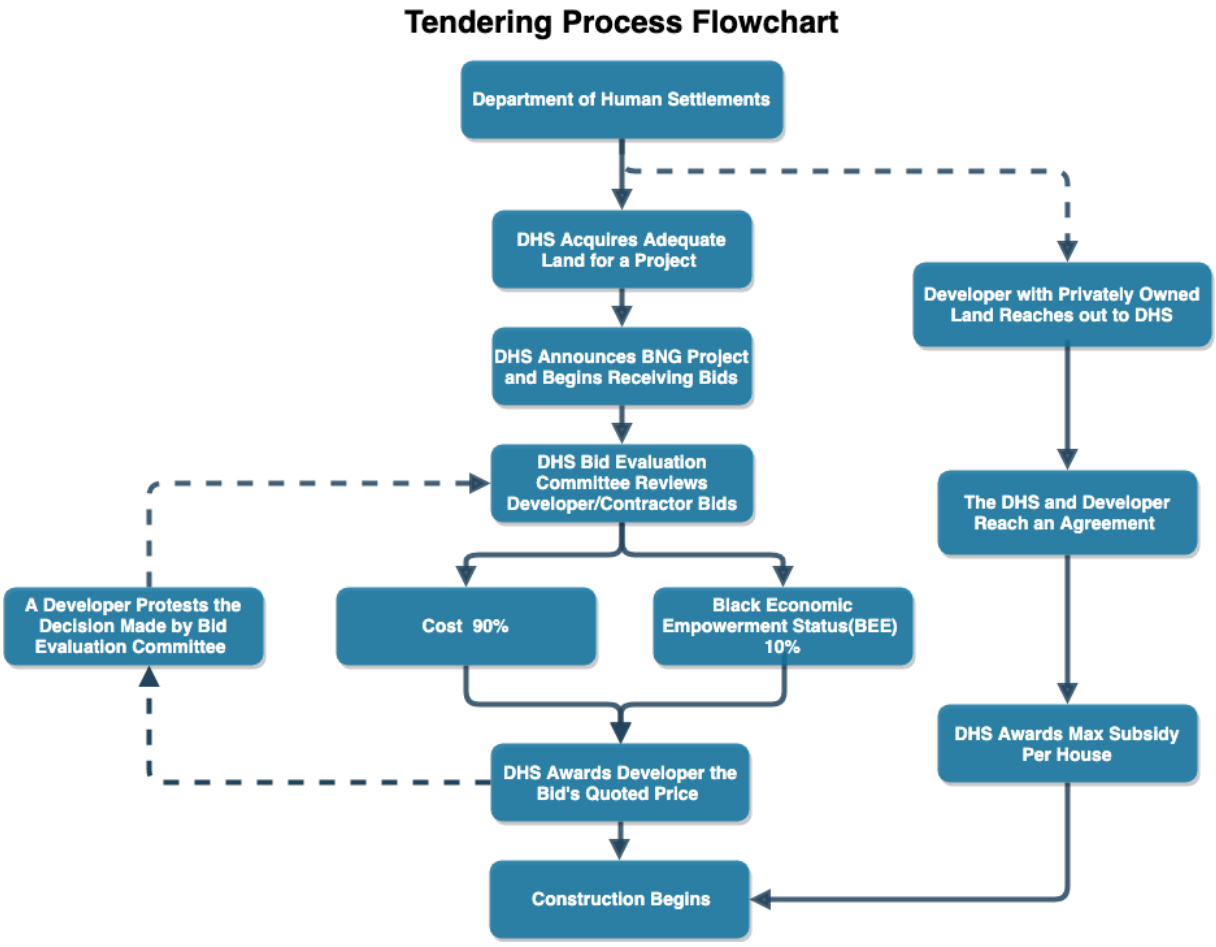

Figure 8: Flowchart of the current tendering process.

Having a complete and readily available supply chain, the chain of events in which raw materials eventually become a finished house, is an important factor that the DHS evaluates

during the tendering process. In home construction the supply chain consists of a manufacturer, who supplies the materials, the contractor, who uses the materials to build the house, and the customer, the individual who buys the finished product, in this case the DHS. In our interview with Mr. Gumede, he explained to us that ABT companies have difficulty tendering for projects because they lack a complete supply chain (D. Gumede, Personal Interview, Oct. 30, 2019). A key issue we found through interviews with ABT companies and contractors is that in South Africa there exists a disconnect between the manufactures of ABTs and contractors in the low-income housing sector. Even though alternative building technologies are available in South Africa, there are an inadequate number of contractors who are knowledgeable on how to use these technologies and thus the supply chain is incomplete. Mr. Gumede told us that if the DHS wants to implement alternative building technologies in BNG housing, they need to find companies that can both supply the materials and build the project themselves or provide training to local builders (D. Gumede, Personal Interview, Oct. 30, 2019).

In the tendering process the DHS also considers where the proposed building technology has been used before and how experienced the contractor is with this technology. According to Simphiwe Rono, a DHS technician, the DHS wants to have confidence in the contractor's ability to complete the BNG project on schedule and provide a quality product. The greater number of houses that have been constructed using the proposed building technology, the more confidence the DHS has that the technology is of good quality (S. Rono, Personal Interview, Oct. 30, 2019). The team found that the tendering process favors building technologies that have been used extensively in the past because these technologies provide a commodity of known quality. Many ABTs are relatively new products and have not been implemented on the same scale as more conventional building methods. Due to this, conventional building materials have an advantage in the tendering process because they are perceived as a more known and proven commodity.

The cost of construction is the most important factor that is considered during the tendering process. In every bid, the contractor quotes the DHS how much it will cost to build an individual BNG housing unit. The quoted price greatly influences who the tender is awarded to because the government grant for BNG housing is a maximum of $8,800 (R130,000) per house. In order to determine which bid to accept, the Bid Evaluation Committee rates each bid using a scoring index. The bid with the highest score is then chosen. According to Mr. Gumede, 90% of the score is influenced by the bid's quoted price (D. Gumede, Personal Interview, Nov. 6, 2019). Companies that bid at a lower price receive a higher score than those who bid at a higher price point. We learned from John Powell, an architect from PWP Architects, that alternative materials are generally more expensive than conventional building methods (J. Powell, Phone Interview, Oct. 31, 2019). Cobus Louw, an employee at Asla Construction, a company that has built BNG housing, agreed with this statement. He explained that Asla Construction does not build BNG housing with alternative materials because it is not cost-effective for the company due to higher costs (C. Louw, Phone Interview, Nov. 20, 2019). The higher costs associated with alternative building technologies put these technologies at a disadvantage in the tendering process because they are more likely to receive a lower score from the Bid Evaluation Committee than bids that utilize conventional methods. This is a major obstacle for the DHS if they wish to implement alternative building technologies in future BNG projects.

It is important to note that we also discovered that it is difficult to compare the price of a BNG house built from ABTs and one built from conventional building materials because there lacks a standard way of measuring price. Some ABT companies gave us the price per square meter of house while others gave us the price per square meter of walling. We also found that

there are a variety of factors that affect the cost of home-building, such as the type of foundation, utilities, and the number of interior walls. ABT companies had difficulty telling us the estimated cost of a 40 square meter BNG home because they did not know these factors. Mr. Louw also explained that Asla Construction only builds a BNG project if it has 250 housing units or more, because otherwise it does not make financial sense for the company. This shows how economies of scale are important to understanding the cost of a BNG project. If you build more houses, you can buy more materials in bulk, and lower the price of each individual house. ABT companies lacked information on how much it would cost to build in scale and could only give us the estimated price of construction based on the assumption it was a single, stand-alone, home. Therefore, our research found that in most cases, homes built from ABTs were more expensive.

Finding 6: Alternative block systems are the most feasible for the DHS to implement in future projects however they do not provide all the advantages that other ABTs can offer.

Alternative block systems are a type of ABT that uses conventional materials and applies them to home-building in new and unique ways. Alternative blocks look like conventional concrete blocks; however, they are made from different composites that improve strength, reduce weight, and increase manufacturability. While there are benefits to using alternative block systems, other ABTs offer advantages that alternative blocks do not. These advantages range from improved insulation to better ventilation. The full list of ABTs and their information can be found in Appendix E. Additionally, block systems tend to be less eco-friendly or sustainable because they often use cement, aggregate, and require a large amount of water. This does not align with the DHS's desire to increase the sustainability of future BNG projects by using more environmentally friendly materials and construction practices. Even though alternative block systems do not provide all the advantages that other ABTs have to offer, the team found that they are easier for the DHS to implement because of their favorable effects on labor, previous experience working with them, positive public perceptions, and cheaper costs when compared to other ABTs.

Alternative block systems have already been implemented in BNG developments in the Western Cape region. During our research the team found multiple companies around Cape Town who supply and build with alternative block systems. The exact companies and their products can be seen in Appendix E. One of these companies, Benex, a manufacturer of composite blocks made from a cement-polystyrene mixture, has already been employed by Garden Cities, a local developer, to build BNG housing in Fisantekraal. While this particular block system is manufactured in a factory, other alternative block systems can be produced on site and can employ unskilled labor. As discussed in Finding 4, the utilization of unskilled labor would allow the DHS to employ community members, involving them in the project and providing economic stimulus to the community. It was also found that several suppliers of alternative block systems offer training for prospective contractors, laborers, and homeowners. The multitude of companies and the abundance of suitable construction workers make alternative block systems a viable option for BNG housing.

As previously discussed in Finding 3 the team found that alternative block systems, like the one used in Fisantekraal, can overcome the general negative perceptions surrounding ABTs and gain acceptance among BNG beneficiaries. When we asked residents in Fisantekraal why they liked the alternative block, respondents cited the block's strength along with the safety and quietness the house provided. Since alternative block systems appear similar in structure and composition as conventional concrete blocks, people associate them as having the same characteristics. Favorable perceptions of the alternative block system in Fisantekraal should

serve as encouragement to the DHS that similar building systems can successfully be implemented in future BNG developments.

Finally, alternative block systems are most viable option for the DHS to implement in new BNG developments because of their lower costs. Through our analysis of the building-costs of different building materials, we found that the cost per square meter of walling is cheaper when using alternative block systems. As seen in Table 2, alternative block systems are the cheapest ABT and more cost-effective than concrete block. This allows contractors who want to utilize alternative block systems to be more competitive in the tendering process, as discussed in Finding 5. Even though alternative block systems may be cheaper and easier for the DHS to implement, the DHS should still consider whether other ABTs better address the DHS's long-term goals of improving the quality of housing and being more environmentally conscious.

Table 2: Cost comparison of different building systems

Building System	Sandbag	Structurally Insulated Panels	Moladi	Alternative Block System	Lightweight Steel Frame with Modular Panels	Concrete Block
Type of Technology	Alternative	Alternative	Alternative	Alternative	Alternative	Conventional
Cost per square meter of walling (R)	No info	450-500	No info	163.48	800	364.71
Cost per square meter of house (R)	4,000-5,000	No info	3,889	No info	No info	2,900
Estimated cost of BNG House (R)	160,000-200,000	No info	155,555	No info	No info	116,000
Estimated cost of walling for BNG house (R)	No info	30,600-34,000	No info	11,116	54,400	24,800

*The estimated cost of walling for BNG housing was calculated based on an estimate of 68 square meters of walling for an average sized BNG house and does not include the cost of labor.

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Limitations

It is important to take into consideration that while our findings are supported by the data collected, these findings still contain certain limitations. The team conducted interviews in four different BNG developments in an attempt to gather data from a variety of sources. However, we only conducted thirty interviews, a relatively small sample size, and not a fully accurate representation of all BNG residents and communities. We also conducted interviews in communities where Afrikaans and Xhosa are the primary languages and some interviewees spoke little or no English. This language barrier may have skewed some of the results because residents did not fully understand the nature of the questions asked. Additionally, in interviews where translation was required, a DHS official served as the translator. This adds a level of bias into the data collected from these interviews because we were not able to hear the residents' direct responses. Instead, we heard a paraphrased version from a DHS official who has an inherit level of bias when discussing BNG housing.

There are additional limitations to consider with regards to the data collected on alternative building technology companies. After extensive research, thirteen alternative building

technology companies were found in South Africa. Of these thirteen, the team was only able to contact and conduct interviews with five. This limited the amount of direct information that we were able to collect on the ABT companies. Also, it is possible we received inaccurate or exaggerated information during interviews with ABT companies because they are trying to market and promote their product to make money. Even though these limitations are important to consider, the team remains confident that the data presented in our findings provides valuable information for the DHS.

Chapter 5: Recommendations

Residents living in BNG housing face a complex array of problems regarding their government subsidized home. Many of these problems can be mitigated through the implementation of alternative building technologies. There are multiple reasons why the City of Cape Town DHS struggles to administer the use of ABTs in BNG developments ranging from current national policy to community perceptions. In the following chapter the team will share recommendations outlining the ways in which the DHS can make alternative building materials a more suitable option for future BNG developments and the specific technologies we believe to be the most effective at improving BNG housing conditions.

Recommendation 1: Reform the tendering process to de-emphasize cost and prioritize factors that more closely align with the DHS's long-term goals.

As discussed in Finding 5, the current tendering process is designed to award a tender to the bidder who bids at the lowest price. This process favors conventional building materials because it places a disproportionate amount of significance on cost and ABTs tend to be more expensive than conventional building methods in South Africa. We recommend that the BNG tendering process be reformed on the national level to de-emphasize the importance of cost and give greater credence to other important factors essential to building a development that will best serve beneficiaries. The scoring index used by the Bid Evaluation Committee should consider the quality, sustainability, and unique design advantages of every bid's proposed building method.

The tendering process needs to be reformed so that the DHS is not forced to sacrifice quality for cost. In any industry, cheaper products tend to be of lesser quality than those that are more expensive. Though there are exceptions to this rule, it can be assumed that BNG projects are being implemented with the cheapest quality construction method and building materials because 90% of the tendering process is decided by cost. The tendering process fails to consider that more expensive building alternatives, that are still within the government subsidy, may provide better quality housing and be more environmentally friendly. Implementing better quality ABTs could reduce the occurrence of maintenance issues described in Finding 1 and increase resident satisfaction with their BNG home. By placing a greater emphasis on the quality of the bid's product in the tendering process, the DHS would be allowed to spend more of the housing subsidy in order to increase the overall quality of BNG projects.

The DHS recognizes that building with conventional concrete blocks is environmentally unsustainable in the long-term. Concrete requires a greater amount of resource extraction than other materials and contains the greatest amount of carbon compared to any other material in the world (Shams, 2011). Additionally, producing concrete requires a large amount of water, which is unsustainable in a region like Cape Town that deals with ongoing severe water shortages. The tendering process should put a greater emphasis on building materials' sustainability so the DHS can prioritize building BNG projects that are more environmentally friendly.

Finally, the reformed tendering process should reward building materials and technologies that provide additional design advantages. These advantages can include, but are not limited to, thermal properties, fire resistance, and ventilation. By placing a greater emphasis on the unique advantages that different building technologies have to offer, the DHS can award tenders based on how bids compare in terms of providing insulation, protecting against fires, and safeguarding public health. Design features, like these should carry weight in the tendering process because they have the potential to greatly improve BNG beneficiaries' quality of life.

We realize that these reforms would require the BNG tendering process to be changed on a national level in South Africa, and this is not within the scope of the DHS's capabilities or powers. However, the City of Cape Town DHS has the opportunity to be a proactive voice for change and encourage the government to focus on the long-term goals of the BNG program instead of being consumed by the short-term financial costs. One way the DHS could initiate these reforms is by sponsoring the development of an intelligent scoring matrix, which could replace the current scoring index and award tenders based on a complex variety of factors that account for the design advantages of ABTs. A flow chart of what the reformed tendering process could be like with the intelligent scoring matrix can be seen in Appendix G.

Recommendation 2: To improve public perceptions of ABTs, the DHS should engage in outreach efforts to inform BNG beneficiaries about ABTs.

The negative opinions of ABTs in low-income communities greatly contributes to the hesitation to use these materials for the construction of BNG housing. Improving public perceptions will be crucial for successfully implementing ABTs in future BNG developments. We recommend that the DHS engages in multiple and continuous outreach efforts in low-income communities to improve the perceptions of ABTs among future BNG beneficiaries.

The first step to doing so is to educate beneficiaries on what ABTs are. As discussed in Finding 3, we found that many beneficiaries are distrustful of ABTs because they do not know what they are. The DHS can begin the process of providing information to beneficiaries about ABTs by distributing the pamphlets, as seen in Appendix F. The DHS can distribute the appropriate pamphlets to future beneficiaries once the tender has been awarded to a contractor and a decision has been made on the building material to be used for the development.

Perceptions of ABTs could also be improved by holding community-meetings where beneficiaries can learn more about various alternative building technologies. These sessions could be held at local community spaces such as libraries or community centers. DHS officials and various alternative building technology companies could give short presentations with information about ABTs. These sessions should also include a Q&A session where residents can ask questions about the technologies to trusted officials. Many residents expressed negative feelings towards ABTs because they felt they could not trust the technology. By teaching community members about available ABTs, beneficiaries may be more willing to trust ABTs because they have a better understanding of what they are.

Lastly, to most effectively demonstrate the quality of a house built with ABTs, the DHS should construct a model BNG house for community members prior to beginning construction on the rest of the development. Allowing community members to help construct the house would further teach them about the material and its specific construction process. Many of the ABTs the team has investigated produce a home which, from the outside, closely resembles a home built with conventional materials. However, when beneficiaries think of materials such as wood or sheet metal they are often reminded of informal dwellings. For this reason, having beneficiaries see the final product will likely increase their trust of the material.

Community outreach prior to the beneficiaries receiving their homes will allow community members to be more informed on the type of house they are receiving. This will help assuage concerns among beneficiaries that they are receiving a substandard house from the government.

Recommendation 3: Improve ventilation in future BNG homes to reduce health risks and improve resident's quality of life.

As mentioned in Finding 2, BNG beneficiaries expressed their desire for improved ventilation in future BNG housing. Residents complained of getting ill and had concerns about the effects that poor ventilation was having on their personal health. Alternative building technologies can address this main concern in two manners. Many ABTs are better at resisting moisture retention compared to conventional concrete, which can improve air quality inside a house directly. On the other hand, certain ABTs can be used in an indirect manner because they can reduce the cost to build the home. This can then free funds that can then be allocated to implement a ventilation system.

BNG residents are currently suffering from poor indoor air quality that poses major health risks especially for individuals who already suffer from respiratory issues. It is imperative that the DHS recognizes that ventilation is a serious concern for the residents and address it by implementing a ventilation solution in future BNG housing. One such solution the DHS should consider is passive stack ventilation. This form of ventilation operates using the buoyancy effect when warm moist air is drawn up threw a ventilation shaft in the bathroom or central location up above the roofline and causes cool air to be drawn in from the outside through windows or trickle ventilators (Ismail, 2012). Adding a ventilation system would incur an additional cost that BNG homes currently cannot afforded. However, BNG homes could be designed in the future with ventilation in mind, possibly allocating funds to address residents' biggest safety concern.

Klevabrick is an ABT that offers an inherently better design than concrete blocks because the Klevabrick blocks are shaped so that they expel rainwater off the exterior walls. The blocks are created with a denser concrete than a standard concrete block, so they are waterproof and do not need to be plastered or painted on the outside. EcoBEAM is a sandbag alternative building technology that utilizes sand as the primary material forming the walls of the structure. If moisture manages to get inside of an EcoBEAM wall the sandbag will not retain moisture and sand is not subject to capillary action like concrete or masonry walls, so moisture will not rise into the walls from the ground (B. Lewis, Phone Interview, Oct. 28, 2019). Ikhaya Future House is a SIP building technology that uses expanded polystyrene as its insulating layer. This material is a common insulating layer used in many SIPs and is both fireproof and resistant to water, making it a material that adds safety and comfort to a BNG home. More information on the previously mentioned technologies can be found in Appendix E and Appendix J. These ABTs improve upon the conventional concrete blocks that current BNG homes are constructed with and create a home that is more resilient to water and moisture migration. If these ABTs were adopted they could improve the ventilation and air quality in future BNG homes.

Recommendation 4: Prioritize building BNG developments using alternative block systems in the immediate future

As noted in Finding 6, alternative block systems are the most viable option for the DHS to implement because they are the most competitive ABT in the current tendering process. Even though they do not afford all the advantages of other ABTs, we recommend that the DHS prioritize building BNG developments using alternative block systems in the short-term in order to increase cost-efficiency and localize labor.

The team found four alternative block systems manufactured in South Africa, Klevabrick, FinnBuilder, Rambrick, and Selcrete that are all either cheaper than or competitive in price with concrete block. Building with alternative block systems will allow the DHS to build BNG projects more cost-efficiently. By reducing the cost of a single BNG housing unit, the DHS can afford to increase the total number of housing units in a development. By building more houses the DHS will also increase the delivery rate of each BNG project, providing housing to more beneficiaries. On project sites where the number of housing units is limited because of land scarcity, the DHS can invest the remaining grant money in providing amenities that improve neighborhood safety in the community, such as fencing and burglar bars on every house. A more in-depth comparison of the mentioned alternative block systems can be found in Appendix H.

An advantage that Klevabrick, FinnBuilder, and Rambrick all afford is that they can be manufactured at the construction site. This benefits the DHS because it simplifies the construction supply chain. The individuals who are making the blocks are also the ones building the house. Additionally, manufacturing the blocks is a labor-intensive process, a quality that should appeal to the DHS because it allows the department to employ more people. Alternative block systems employ unskilled labor, allowing the DHS to localize labor and provide economic stimulus in the immediate community where the BNG project is being built. If the DHS decides to build a BNG project using these technologies, we anticipate that in the beginning there will be a lack of knowledge on how to implement them. However, the three companies mentioned above also offer training programs. We recommend that for the first few BNG projects the DHS pay for local workers to receive training.

Recommendation 5: Partner with local non-governmental organizations and ABT companies to finance and build emergency housing for BNG beneficiaries.

As mentioned in Finding 5, the current tendering process and other external factors makes it difficult for the DHS to implement alternative building technologies in BNG projects. In Recommendation 1 the team advocated for the tendering process to be reformed so that new building technologies can be more competitive in the tendering process and be utilized more often. However, we realize this would require an institutional change to how the South African government builds BNG projects and reforms would take years. Therefore, in the short term, we recommend that the DHS form partnerships with nonprofit organizations and ABT companies to finance and build low-income housing using ABTs on behalf of the DHS.

These partnerships are not meant to build entire BNG projects, but rather small-scale projects of one or two houses in emergency circumstances. We learned from Mr. Gumede that if a BNG beneficiary's home is destroyed by a fire or made unlivable by another accident that is not of the beneficiary's doing, the DHS will build a new house for the beneficiary. He further explained that even though emergency housing does not have to go to tender, the process is slow because it can take a long time for the DHS to acquire the funding for rebuilding the house. Since the tendering process does not apply to emergency housing, the DHS has more freedom to rebuild the destroyed house using ABTs. By collaborating with nonprofits and ABT companies to build emergency housing, the DHS can implement alternative building technologies in BNG housing at no cost to the DHS. These partnerships also allow the DHS to gain valuable insight into how they can implement alternative building technologies themselves in the future. Additionally, the DHS can use emergency housing built from alternative materials to spread awareness of ABTs among BNG beneficiaries and show the public that ABTs can be used to

build quality housing. This can help change negative perceptions of non-conventional building materials and aid the long-term goal of implementing ABTs in entire BNG projects.

Habitat for Humanity and The Development Action Group are two non-governmental organizations located in Cape Town that have extensive experience building low-income housing. A more in-depth description of each NGO can be found in Appendix I. From our research and interviews with ABT companies we discovered that EcoBeam and Moladi have already built houses in collaboration with NGOs around South Africa. Due to their previous experience, these should be the first companies that the DHS reaches out too. The contact information for EcoBeam and Moladi, along with the other ABT companies, can be found in the resource guide in Appendix E. Appendix J provides more technical information on EcoBeam, Moladi, and other ABTs. It will be important to convey to these companies and organizations how building emergency housing using ABTs will help promote the use of ABTs in future BNG projects and improve the quality of housing that BNG beneficiaries receive. This way, the involved parties can be confident in knowing that their involvement, money, and work will be going to good use and improving people's lives.

Conclusion

As the need for low-income housing in Cape Town continues to grow, the South African government will need to find new solutions to alleviate the city's housing shortage. Alternative building technologies have the potential to be one of these solutions. The City of Cape Town Department of Human Settlements seeks to find and implement new building technologies in order to improve the delivery rate and quality of BNG housing. Our investigation into the conditions in BNG housing and exploration of alternative building technologies is intended to serve as a foundation that the DHS can use to build low-income housing utilizing alternative materials.

Future work is needed to implement alternative building technologies in BNG projects; however, the team is confident that our research and recommendations will help the DHS begin the long process of making alternative materials more prevalent in BNG housing. While the DHS and BNG beneficiaries can benefit from our short-term recommendation of implementing alternative block systems, it is critical that the department also looks to the future. In the long-term, institutional reforms to the tendering process and a commitment to community engagement are necessary for the DHS to be able to implement any type of ABT that it thinks best accomplishes the BNG program's ultimate goals.

Not only can alternative building technologies improve the quality of housing that BNG beneficiaries receive, they can also assist other housing needs in Cape Town. Alternative building technologies could be used to upgrade housing conditions in informal settlements or make temporary housing for people displaced by fires or natural disasters. With a commitment to implementing alternative building technologies in low-income housing, the DHS can be at the forefront of transforming lives through innovative building solutions.

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Appendix A: Resident Interview Questions

We are students from Worcester Polytechnic Institute (WPI), a University in the United States of America. We are conducting a research project to assist the City of Cape Town's Department of Human Settlements improve future BNG housing. We would like to ask you some questions about your house so that we can learn from you and include your views in our report to the Department of Human Settlements. We are hoping to learn about your satisfaction with BNG housing and any safety issues in your home. We are also interested in your perceptions of different building materials.

Before we begin, we would like to thank you for taking the time to participate in the interview and want to let you know that your participation is completely voluntary. You may choose not to answer any questions or end the interview at any time you feel uncomfortable. With your permission we would like to record the interview in case we can't remember everything. The notes of the interview will be kept confidential and will be accessible by only the members of the team and our immediate supervisors. Your name will not be used in any report or publication. The interview is expected to take 30-45 minutes. You can contact us at any time via email at gr-CT19-Buildings@wpi.edu. You may also contact our WPI project advisor, Melissa Belz, at mbelz@wpi.edu. and Thidi Tshiguvho, at thidinalei@yahoo.com. Do you have any questions before we begin?

Satisfaction Assessment

1. How long have you been living in this house?
2. How many people live in this house with you?
3. Where were you living before you moved here?
4. Do you think living conditions in your house are an improvement from your previous living conditions?
    a. Can you explain why you feel this way?
5. On a scale of one to five, five being most satisfied, how satisfied do you feel with your BNG house?
    a. Can you explain what made you pick that number?
    b. What do you think about the construction quality of your house?
    c. Do you like the materials your house is built from?
    d. Can you tell us why you think that about the materials?
6. Have you ever experienced maintenance problems in your house?
    a. Can you describe these problems in more detail?
    b. Have you ever had to use your own money to make repairs to your house?
    c. What would you like to improve in your house?
7. In your opinion, how could the government improve the quality of low-income housing?
8. Have you ever considered leaving government housing and returning to your previous living arrangements?
    a. If you have considered this, why?

Evaluating Safety

1. Have you ever felt that you or your family were unsafe in your home because of maintenance problems in your house?
    a. Can you elaborate on these problems?
    b. How have they effected your family's safety?
    c. Do you think these problems were caused by poor construction?
2. Did you or a family member have an accident or injury because of defects in your house?
3. Has your community ever had fires?
    a. Do you know how the fire started?
    b. Was your house damaged by the fire?
4. What are some safety-improvements you would like to see in new BNG housing?
5. Are there any particular aspects of your house that make you feel safe?

Public Perceptions

1. What type of building materials would your ideal house be constructed from and why?
2. How would you feel if your house was not made of brick or concrete?
3. On a scale from 1 to 5, where 5 is best and 1 is worst, can you rate the quality of a house built from the following materials?
    a. Brick
    b. Concrete blocks
    c. Wood
    d. Sheet Metal
    e. Sand or Mud
4. Can you tell us more about why you think this way about [material]?
5. Do you think a house's building materials reflect a person's wealth and social status?
6. Are you familiar with the term "alternative building material"?
    a. If no, explain: Our group defines alternative building materials as a material other than brick or concrete that is used to build BNG housing.
    b. If yes, can you explain how you define alternative building materials?
7. Are you familiar with any alternative building materials being used for BNG housing?
    a. If so, what do you think about these new materials and techniques?
    b. Have you heard stories from other people about their experiences living in houses built from alternative materials?
8. How would you feel if your home was built from alternative building materials?
    a. Would you be willing to live in a house that was built using alternative building materials?
9. What is your opinion of multi-storied apartment buildings?

Appendix A.1: Modified Public Perception Interview Questions

1. What type of building materials would your ideal house be constructed from and why?
2. On a scale from 1 to 5, where 5 is best and 1 is worst, can you rate the quality of a house built from the following materials?
    a. Brick
    b. Concrete blocks
    c. Wood
    d. Sheet Metal
    e. Sand or Mud
    f. The material your house is built with
3. Can you tell us more about why you think this way about [material]?
4. Do you think a house's building materials reflect a person's wealth and social status?
5. Before moving in were you told your house would be made from an alternative building material?
    a. How did you feel when you were told this?
6. What did you first think about living in a house built from an alternative building material?
7. Have those thoughts changed since you've started living here?
    a. Why or why not?
8. Compared to conventional brick and cement block, do you think the quality of this new material is worse, better, or the same?
    a. Can you explain why you think this?
9. Would you encourage others to live in a house built like yours?
10. What is your opinion of multi-storied apartment buildings?

Appendix B: Department of Human Settlements Staff Member Interview Questions

We are students from Worcester Polytechnic Institute (WPI), a college in the United States of America. We are conducting a research project to assist the City of Cape Town's Department of Human Settlements improve BNG housing through the implementation of alternative building technologies. We would like to ask you some questions about the BNG housing implementation process and obtain your opinions on how this process can be improved.

Before we begin, we would like to thank you for taking the time to participate in the interview and want to let you know that your participation is completely voluntary. You may choose not to answer any questions or end the interview at any time you feel uncomfortable. With your permission we would like to record the interview in case we can't remember everything. The notes of the interview will be kept confidential and will be accessible by only the members of the team and our immediate supervisors. Your name will not be used in any report or publication. The interview is expected to take 10-15 minutes. You can contact us at any time via email at gr-CT19-Buildings@wpi.edu. You may also contact our WPI project advisor, Melissa Belz, at mbelz@wpi.edu. and Thidi Tshiguvho, at thidinalei@yahoo.com. Do you have any questions before we begin?

1. Who decides what type of building material is used to build a BNG development?
    a. How does that decision process work?
    b. What factors are considered when making these decisions?
2. What building materials are used when building low-income houses?
    a. How often are these materials used?
3. Have alternative building materials been used to construct BNG housing before?
    a. If so, where?
    b. How did the public respond to living in a house built from alternative materials?
4. What parts of the BNG housing implementation process need to be improved?
5. What are some of the key improvements you would like to see in new BNG housing?
    a. In what ways do you think alternative building materials could help improve BNG housing?
6. What is the average cost of building a BNG house?

Appendix C: Key Informant Interviews

We are students from Worcester Polytechnic Institute (WPI), a college in the United States of America. We are conducting a research project to assist the City of Cape Town's Department of Human Settlements improve BNG housing through the implementation of alternative building materials. Because of your previous experience working with alternative building materials, we believe you are uniquely qualified to give us insight into how these technologies can be further implemented in the city. We would like to ask you questions about this topic so we can learn from you and include you views in our report to the Department of Human Settlements and on our school's website.

Before we begin, we would like to thank you for taking the time to participate in the interview and want to let you know that your participation is completely voluntary. You may choose not to answer any questions or end the interview at any time you feel uncomfortable. With your permission we would like to record the interview in case we can't remember everything. The notes of the interview will be kept confidential and will be accessible by only the members of the team and our immediate supervisors. Your name will not be used in any report or publication. The interview is expected to take 30-45 minutes. You can contact us at any time via email at gr-CT19-Buildings@wpi.edu. You may also contact our WPI project advisor, Melissa Belz, at mbelz@wpi.edu. and Thidi Tshiguvho, at thidinalei@yahoo.com. Do you have any questions before we begin?

1. How many houses have you built using [name of technology]?
2. What is the cost of each house?
3. How long is the construction process?
4. What is the biggest advantage that [name of technology] affords to residents?
5. How receptive have low-income communities been to your technology?
    a. Have you had to make outreach efforts to educate people on your building technology?
    b. Have these efforts been successful in changing public opinion?
6. What are the biggest challenges you have experienced when implemented [name of technology]?
7. Have you worked for or in collaboration with the Cape Town government before?
8. Do you know of any other companies or individuals who are currently working with alternative building technologies in Cape Town?

Appendix D: Observation Note Sheet

Address	Exterior Observations	Interior Observations	Other

Appendix E: Alternative Building Technology Resource Guide

The following appendix is a resource guide, meant to be given to the Department of Human Settlements, that presents information on different alternative building technology suppliers in South Africa. All the information was gathered through interviews with companies or off companies' websites. The resource guide identifies the companies and alternative building technologies that the department can consider when building future BNG developments. The appendix provides a range of information that the department can use to begin their investigation of alternative building technology suppliers and explore their technologies.

Name & Image	Description	Cost (per m^2)**	Advantages	Disadvatages	Construction Company	Contact Info
Benex						
	Blocks are made of sand, cement, and polystyrene, interlocking block design, bonded with polyurethane adhesive	N/A	Light weight blocks, better insulator than concrete blocks Semi-skilled laborors, plaster not needed	Easily damaged, blocks cannot be formed onsite	Garden Cities	https://www.benex.com.au (021) 558-7181
EcoBEAM						
	House is built with a timber frame. Sandbags are used for the strucutre of the home. The home is then plastered.	R4,500	•Bullet proof •Fireproof •Eco-friendly •improved insulation	•Expensive •normally used to convert informal dwellings to formal dwelling • not gone to scale	Ubuhle Bakha Ubuhle (UBU)	http://ecobeaminternational.co.za Barry Lewis: +27 (83) 327-3045
Eco Build Sandbag Building*						
	House is built with a timber frame. Sandbags are used for the strucutre of the home. The home is then plastered.	R4,500	•Bullet proof •Fireproof •Eco-friendly•20-30% cost reduction •improved insulation	•"We do not involve ourselves in the construction of renovation work, low cost or mass housing projects"	N/A	https://www.ecobuilders.co.za Andy Strydom: +27 (83) 445-5123
Eco Building Systems*						
	They offer a range of eco friendly thermally insulated building products. Produce expanded polystyrene hollow blocks that is then filled with concrete and reinforced with steel.	R3,000	•light weight • insulating • water resistant •experienced •reduction of cracks •reduced concrete •built model BNG homes •fire resistant	•use concretes •training required	N/A	https://www.ebsystems.co.za +27 (11) 822-5252
FinnBuilder*						
	Use FinnBuilder machine to make walls by compressing concrete mix into a brick-like shape	R 163.48	•can be used to build double & triple stories •faster construction time •labor intensive	•requires the purchase of a machine •requires labor training	N/A	http://finnbuilder.co.za +27 (11) 705 1897

HWZ International Wood Solutions*						
	Use Novatop technology to construct house frames made completely of wood	N/A	•waterproof •fire resistant •high strength and stability	•insulation is required and adds to the cost •appears to cater to more high end housing •panles are manufactured in the Czech reuplic •Panels are heavy and make transportation difficult	N/A	https://www.hwzinternationalsa.co.za +27 (76) 401-9120
Ikhaya Futurehouse						
	They are pre-fabricated panels composed of an expanded polystyrene core encapsulated in mesh. Walls are plastered.	R550	•thermallly insulating •easy construction process •sound and water resistant •can build up to three stories with one panel	•light-weight panels can be difficult to work with in windy conditions •construction company has little interest in working with BNG homes	Amor Ministries: Zingisa Mapasa +27 (82) 883-3828	Jacque Sherman: +27 (82) 770-3027 jacque@futurehouse.co.za
Klevabrick						
	House is built with bricks that can be bolted together. No mortar is necessary	R2,400	•can be manufactured on site •mold is designed for unskilled labor•well perceived by the public •can build up to three stories	• only ever built two-test homes •lack experience •requires the purchase of a mold •ventilation problems could persist	N/A	Duncan Kretzmann: +27 (72) 305-9205 duncan@klevabrick.co.za
Moladi						
	Light weight panels are used to create a mold for a house. A mortar mix is poured into the cavities.	R3,889	•"one-stop shop" •33 years of experience •employ unskilled labor •little maintanence •precise •secure •earthquake resistant	•expensive •extensive training required	N/A	Hennie Botes: +27 (84) 657 4028 mail@moladi.com
Rambrick*						
	The RamBrick™ system converts waste soils and rubble from landfill into building products for all types of housing. Machinery is used to compress the mixture into the compressed earth bricks (CEBs) that we refer to as the RamBrick™ system.	R2,610	•Environementally friendly •Thermally efficient •bulletproof •waterproof •fireproof •creates jobs	•Brick making machinery is imported •Two day training program to use •5 day course for operation of machinery •bricks are heavy and difficult to transport	N/A	Tim Bettany: +27 (76) 895-9902 tim.use.it@gmail.com

Selcrete*						
	Wall blocks are made by mixing cement, polystyrene, and Selcrete additive. Selcrete walls blocks laid in stretcher block method with mortar.	N/A	•Wall blocks are lightweight •Manufactured on site •Fungi and bacteria resistant •Can build up to three stories •low carbon-footprint minimal maintanence	•can be easily cracked and dented	N/A	https://selcrete.co.za info@selcrete.co.za
Shipping Containers						
	An old shiping container can be converted into a home.	N/A	•"up-cycling" - good for the environment •fast delivery •portable	•eliminates opportunities for jobs •would need multiple containers per home •Big Box Company doesn't design containers homes themselves	N/A	https://www.berman-kalil.co.za hello@berman-kalil.co.za
Trumod						
	Panels slide into tracks attached to a cement foundation and bolted into placed.	R900	• uses unskilled labor •experienced •no waste on site because everything is manufactured precisely with CNC machines • thermally efficient •simpler foundation	•manufacturer simply provides the panels	AMMS: Alex Murray +27 (82) 259-3746	Tony Da Silva: +27 (71) 896-7089 tony@trumod.co.za
UCO SolidWall Building System*						
	UCO SolidWall Building System is made up of UCO Flexabord fibre cement sheets that are fixed onto steel studs and infilled with a lightweight concrete mix	N/A	•Lightweight •Quick to install •Durable •Water-resistant •Fire-resistant	•uses cement & concrete •frame must be shipped to site	N/A	+27 (21) 933-0052 info@ufcc.co.za
						*companies not interviewed
						**rough estimate of cost

Appendix F: Alternative Building Technology Infographics for Residents

In this Appendix, we present infographics that the team created for four different alternative building technologies: structurally insulated panels, block-based building, moladi, and sandbag building. These infographics are meant to be given to BNG beneficiaries by the Department of Human Settlements to help inform people about alternative building technologies and improve perceptions of new building materials. Each infographic shows pictures of the building technology, explains the construction process, and presents the advantages that each building technique affords.

Alternative Building Technologies

SANDBAG BUILDING

How Does it Work?

1. A timber frame is constructed
2. Sandbags are stacked into the frame
3. A fiber mesh and plaster are put on the walls

Advantages

- **Acoustically Insulating**
- **Bulletproof**
- **Thermally Insulating**
- **Water Resistant**
- **Fireproof**

Alternative Building Technologies

MOLADI

How Does it Work?

1. Moladi panels are assembled to form a mold for the house
2. A mortar mix is poured into the cavities of the mold
3. The panels are removed and the walls are plastered

Advantages

- **Brick-like Qualities**
- **Provides Jobs**
- **Increased Strength**
- **Precise Building**

Alternative Building Technologies

BLOCK-BASED BUILDING

Different Variations

Material

The material of the brick can be altered to reduce weight, increase strength, or provide better insulation

Construction

Blocks can interlock or be bolted together to avoid the use of mortar during construction

Production

Blocks can be manufactued on site with the right machinery

Advantages

Increased Strength

Easy Construction

Provides Jobs

Alternative Building Technologies

STRUCTURAL INSULATED PANELS (SIPS)

How Does it Work?

1. Panels are manufactured at company and transported on site location
2. Panels are assembled on site to create the framework of the house
3. A finish is put on the panels, usually plaster and paint

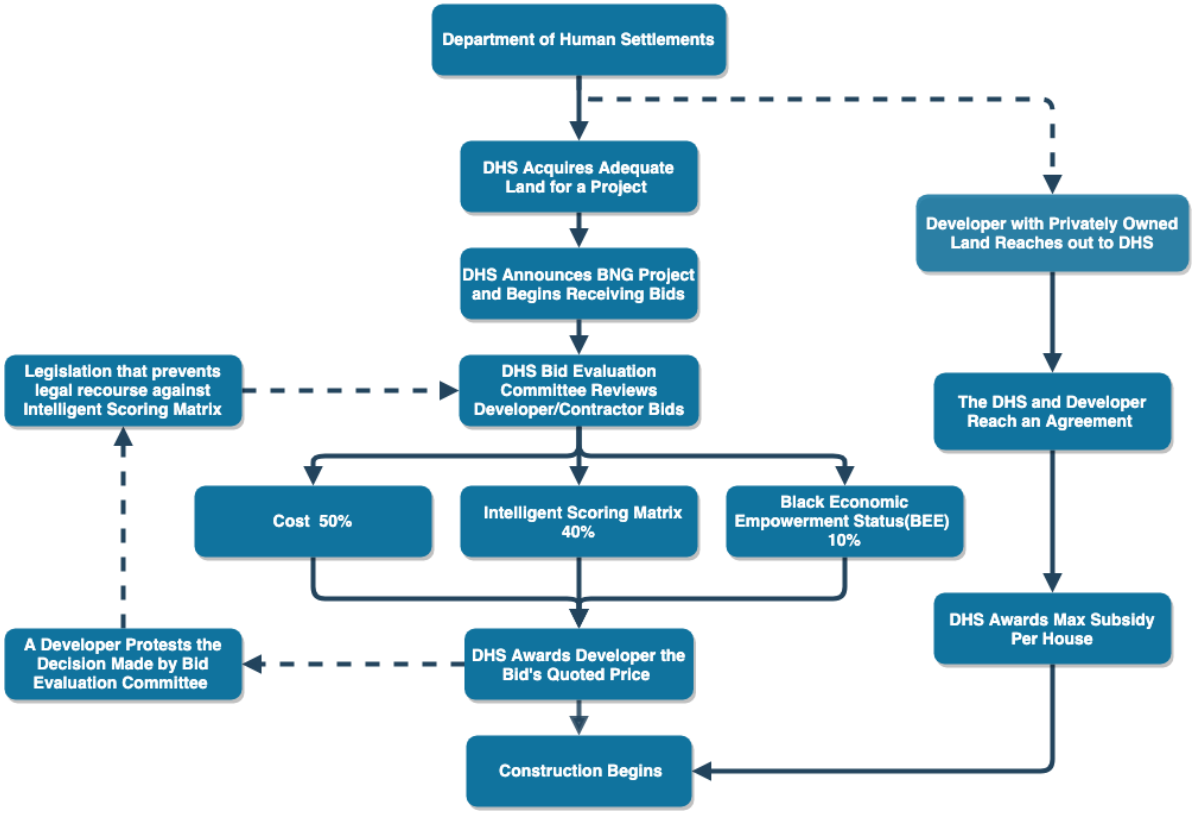
Advantages

- **Acoustically Insulating**
- **Easy Construction**
- **Thermally Insulating**
- **Water Resistant**
- **Fire Resistant**

Appendix G: Proposed Tendering Process Flowchart

This Appendix is a flow chart of the tendering process based on the recommended reforms the team made in Recommendation 1. The team recommended that the current tendering process for BNG projects should be reformed by the South African government so that the importance of cost is de-emphasized, and other factors are given more influence. The major change is how each bid is scored by the Bid Evaluation Committee. The flow chart shows a hypothetical scoring index that is decided by the following factors: 50% cost, 40% intelligent scoring matrix, and 10% black economic empowerment status. The intelligent scoring matrix considers the properties of different building systems, such as their insulation, ventilation, fire resistance, and sustainability qualities. The team recommended the Department of Human Settlements invest in creating an intelligent scoring matrix because one does not yet exist.

Proposed Tendering Process Flowchart



Appendix H: Comparison of Alternative Block Systems

In the short-term, alternative block systems are the easiest alternative building technology for the Department of Human Settlements to implement with the current tendering process because of their comparable price to concrete blocks and past instances of being used to construct BNG developments. The table below compares five alternative block systems that are available in South Africa. The listed information can be used by the DHS to make an informative decision on which alternative block systems to implement if they choose to do so.

Alternative Block System	Benex	FinnBuilder	Rambrick	Klevabrick	Selcrete
Description	Blocks are made of sand, cement, and polystyrene. Has an interlocking block design and bonded with a polyurethane adhesive.	FinnBuilder machine used in slip-form system to form walls by compressing no-slump concrete into block shape.	Block are made of waste soil and rubble. Machines are used to compress the materials into bricks and slurry is used to bond the bricks.	Blocks are made from in molds from high density concrete reinforced with 6mm galvanized rods. Blocks are finally bolted together.	Blocks are made of cement, polystyrene and Selcrete additive -Mortar is used in construction
Advantages	-Light weight blocks, -Better insulator than concrete blocks	-Increased rate of construction -Strength of the concrete can be varied -Trained subcontractors available	-Recycles material for construction, only 5% cement -Increased rate of construction	-Stronger than hollow concrete blocks (25 MPa rating) -Block design expels rainwater from walls -Increased rate of construction	-Lightweight -Better insulator than concrete blocks -50% larger blocks increase rate of construction
Disadvantages	-Easily damaged -Blocks cannot be formed onsite	-FinnBuilder forms need to be purchased -Training is required	-Rambrick machines must be purchased and are imported from United States.	-Only 2 concept houses have been constructed -Molds need to be purchased	-Easily damaged -Blocks cannot be formed onsite
Labor	-Semi-skilled labor Plasterer not needed	-A trainee can complete 10 m² of walling a day	-Bricklayers required -Plasterer not needed	Manufactured onsite Unskilled labor No masons or bricklayer needed	-Bricklayers and plasterer needed
Environmental	-No mortar needed -Polystyrene can be harmful to environment	-No mortar needed -Concrete requires large amounts of water	-Reused buildering rubble and waste soil. -Only 5% cement -CO2 emissions savings.	-No mortar -Concrete requires large amounts of water	-Blocks are 100% recyclable -Concrete and mortar require large amounts of water
Perceptions	Looks like conventional concrete block home Beneficiaries do not like that it sounds hollow	Looks like concrete plastered home when complete	Looks similar to clay brick homes, which beneficiaries find aesthetically pleasing	Looks similar to conventional concrete block and is very strong	Looks like conventional plastered home when complete
Cost	Used by Garden Cities for BNG homes	R163.5 (per m² of vertical walling)	R2,610 (per m² of home)	R2,400 (per m² of home)	Comparable to concrete blocks

Appendix I: Housing Non-Governmental Organizations

In Cape Town there are two NGOs that are involved with providing low-income housing to disadvantaged individuals and communities. Contact with these organizations should be initiated in the short-term future to form a partnership between the DHS and other ABT companies to build BNG housing in emergency circumstances.

- **Habitat for Humanity South Africa**: Habitat for Humanity is a non-profit organization that works to alleviate poverty by providing low-income housing and engaging community participation and empowerment in the delivery of housing and informal settlement upgrading.
- **Development Action Group**: The Development and Action Group is a non-profit organization that works to address the underlying causes of poverty and inequality in urban areas. They have over 30 years of experience and to date have successfully delivery 7,323 new homes for the urban poor.

Organization	Contact Information	Address
Habitat for Humanity South Africa	Phone: +27 21 657 5640 Email: info@habitat.org.za Website: https://habitat.org.za/	Office 201 Pine Park, 1 Logan Way, Pinelands, Cape Town, 7405
Development Action Group	Phone: +27 21 448 7889 Email: dag@dag.org.za Website: https://www.dag.org.za/	101 Lower Main Road, Observatory, Cape Town, 7925

Appendix J: Alternative Building Technology Resource Sheets

The following appendix expands on the information given in the Alternative Building Technology Resource Guide found in Appendix E. The resource sheets provide more extensive description of the technical aspects of each alternative building technology along with other information that the DHS might find helpful.

EcoBEAM

SANDBAG BUILDING

Overview

- The building system is comprised of a timber frame structure, consisting of timber lattice beams (Eco-Beam) as vertical and horizontal studs
- The Eco-beams are fabricated from two 38 mm square treated timber sections (SANS 10005) and connected by a continuous galvanized steel strap which zig-zag between the timbers to form a lattice beam 220mm deep
- Sand is placed in a polypropylene bag
- Sandbags are stacked between the beams
- The walls are finished by securing steel wire mesh on both sides of the frame structure and plastering with conventional cement-sand plaster 25mm thick.
- The foundation is generally a concrete strip footing
- Concrete columns are added for multi-story buildings

Advantages

Material Properties

- Fireproof
- Bulletproof
- Water resistant
- Breathable bag allows moisture to run to the bottom and not get stuck in the walls
- Wooden beams allow for ventilation
- Thermally insulating
- Acoustically insulating

Labor

- Community can self-build houses
- Creates jobs in the community

Perceptions

- Hesitation at first however once residents see a completed house they are more accepting
- Community based approach can help perceptions

Disadvantages

- Currently working on transforming informal settlements
- Construct houses one at a time
- Have not gone to scale

Contact Info

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FinnBUILDER

ALTERNATIVE BLOCK SYSTEM

About the Technology

- Slip-form concrete shuttering using no-slump concrete
- Concrete mix with a generic ratio of 2 parts 13mm concrete stone, 3 parts river sand, 3 parts building sand and 1part cement but mixture will vary depending on building location
- Concrete varies from 5 MPa to 40 MPa
- Takes 15 hours for a row of cement bricks to dry
- About 20m^2 of vertical walling can be put up in a day
  - A trainee will complete about 10m^2
  - A bricklayer will complete about 7m^2 of vertical walling (800 bricks) a day
- Use FinnBUILDER machines to build
  - Pillar Machine: Used to make columns for structural support
  - Gemini Machnine: Used to build walls
- Winner of the Eric Molabi Housing Innovation Hub
- Used in both high end and low cost construction

Advantages

Material Properties

- Faster construction times
- Can be used for building double and triple stories
- Double the strength of brick

Labor

- Trained Subcontractors Available
- Ability to construct the exterior of a low cost house in 4 days

Cost

- Cost of FinnBUILDER per square meter estimated to be R 165 where as cost of brick estimated to be R 320 per square meter

Other

- Fully accredited and backed by major banking institutions

Disadvantages

- Require 5 day training course before being eligable to use machines
- Need to buy machines

Contact

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HWZ International Wood Solutions

WOOD BUILDING

Overview

About the Company

- They are a division of Kuratle group, a Swiss company which is active all over the world. The Kuratle group and its partners intend to promote wood construction and green building in South Africa.
- Range of services and products includes different types of wood, construction materials, i.e. plywood, sawmill timber, finger joint beams, and glue laminated beams, flooring, facade covering, systems for insulation and sealing and building boards

About the Technology

- Novatop Cross Laminated Timber (CLT)
  - CLT consists of three layers
    - Each layer of the panel consists of lamellas of massive solid wood. The lamellas of the middle layer are glued longitudinally, and the outer layers are made of continuous lamellas
  - The wood is dried to a moisture content of about 8%; to ensure high stability of components and prevent cracking
  - The adhesive used is waterproof and surface lamellas are glued according to AW100

Advantages

Material Properties

- Fire resistant
- Individual components are characterized by high strength and stability in the compressive stress and tension and exceptional static strength
- Can be applied to walls, ceilings and roofs, and the result is a massive and really safe all-wood construction
- Energy-efficient
- Air-tight
- Breathable (Water Resistant)
- Acoustically Insulating
- Thermally Insulating

Construction

- High accuracy construction
- Faster construction times

Perceptions

- Novatop CLT is being used in high-end houses so perhaps BNG beneficiaries might be more willing to accept a CLT-built house if they know wealthy people also use the technology

Disadvantages

- Insulation is required which increases the total cost of the house
- Caters to the high-end housing market
- Panels are manufactured in the Czech Republic
- Wall panels are very heavy and require cranes and forklifts to handle
- Since it's a wood building system people could be resistant to accepting it

Contact Info

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Novatop

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Ikhaya Futurehouse

STRUCTURALLY INSULTED PANEL

About the Technology

- Walling system made of pre fabricated light modular panels with a high density, expanded polystyrene core encapsulated in a wire mesh
  - Wire mesh is electro-welded to galvanized wire ties passing through the expanded polystyrene core.
  - Panels are finished off with structural plaster on both sides of the wall to give the house a smooth finish
  - Reinforced concrete ring beam is cast at eaves level to all and gable walls
  - External corner and T-wall junctions are reinforced with U-shaped reinforcing bars at 250mm centers, passing through the EPS core with the legs in either side of the junction wall
  - Internal wall junctions are reinforced with L shaped strips of weldmesh wire tied to the wall panel weldmesh
- Panels are supplied in standard sizes 12 m wide x 2.5m, 2.75m, and 3m height
  - Custom hieghts can be made to order up to a maximum of 6m hieght/length
- Expanded Polystyrene (EPS) thickness variants of 40, 60, 80, and 100mm depending on insulation requirement
- Walls are constructed by placing the panels in a grid of started bars drilled in the foundation, wire tied together, braced, and then plastered
- Plaster is 20mm above the mesh before plastering
- Windows and doors openings are cut out of panels
- Any roof system can be used with the panels
- Roof trusses are either placed directly onto the plastered panels and tied to the mesh or alternatively fixed to a wall plate or concrete ring beam

Advantages

Material Properties

- Thermally and acoustically insulating
- Energy saving: Meets regulated energy efficiency building codes
- Water resistant
- Panels are lightweight and easy to transport
- Can build up to 3 stories tall with single panel

Labor

- Quick and easy construction
- Bulding speed is greater than 10 times that of brick and block
- Can be built with unskilled labor
- Can build a house in 15 weeks

Perceptions

- Look, sound, and feel of a concrete or plastered brick wall

Past Projects

- Mozambique, Botswana, and Zimbabwe
- Has been used to build mining houses which are similar in size to BNG houses and are low-cost

Disadvantages

- The panels are very lightweight so before the plaster is applied the panels can be cumbersome and difficult to work with especially when it is windy
- Only requires 4 to 5 people to build a house

Contact Information

- https://www.futurehouse.co.za/
- info@futurehouse.co.za
- (012) 653 1938

Klevabrick

ALTERNATIVE BLOCK SYSTEM

Overview

- Klevabrick follows traditional building method of normal brick except adjacent blocks are bolted together rather than by the use of mortar
- First course of Klevabrick is bolted into the floor slab
- Requires 25mpa concrete, galvanized reinforced 6mm round bar, molds
- Bricks can be made on site by pouring concrete into the mold
  - Molds last 8 years
- 8mm bolts are used to connect adjacent Klevabricks
- Two 20mm conduits are cast into every Klevabrick
- There are various brick types: interior, exterior, window sill and foundation

Advantages

Material Properties

- Can built up to three stories
- Expels rainwater from exterior walls
- Plaster finish & oxide gives maintenance/paint free surface

Construction

- It is designed to create employment.
- The mold is designed for unskilled labor
- The blocks can only sit one way
- Can be manufactured on site
  - Made locally, provides local improvement
- They have RDP house plans
- Without mortar it removes the need for bricklayer

Perceptions

- The system uses concrete blocks which makes it easier for people to accept

Disadvantages

- Since it is concrete block ventilation problems could persist
- Have only built 2 test-units
- House has a ship-lap profile which is different from the smooth surface look of traditional brick houses
- Molds need to be purchased

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Moladi

MOLD BASED BUILDING

Overview

- House is constructed with a reusable lightweight mold formwork
  - The formwork is bolt-less and free-standing
  - The panels can be reused up to 50 times
- An aerated mortar mix is poured into the cavities of the mold
  - Mortar mix is essentially concrete without stone
- The mortar mix dries overnight
- The moladi panels are removed after the mortar dries
- All the walls are reinforced with steel
- The walls are painted
  - No plaster is required
- Won the Eric Molabi Competition for the subsidy category
- Been in business for 33 years

Advantages

Material Properties

- Brick-like qualities
- Increased strength
- Waterproof
- Little maintenance difficulties long term

Construction

- More opportunity for unskilled labor jobs
- Set up co-ops in communities to teach people skills to contribute
- No plastering

Perceptions

- To combat negative perceptions future residents took an ax to a Moladi home and were able to see for themselves how strong it is

Disadvantages

- Tend to avoid going to tender
- Training is requireed to learn how to build using moladi

Contact Info

Moladi

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Hennie Botes

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Ram Brick

ALTERNATIVE BLOCK SYSTEM

Overview

- The RamBrick system converts waste soil and rubble from landfills into building products for all types of housing
- Produces have a third of the carbon footprint than conventional materials
- Manufactured from 95% recycled materials
- The bricks are composed of 25% mixed inert builders waste, 5% stabilizing agent, and about 70% soil, depending on the soil type available
- Machinery is used to compress the soil, mixed waste, and cement stabilizer mixture into the compressed earth bricks (CEBs)
  - Current RamBrick dimensions are 180x356x88mm used for both interior and exterior walls
- Developed through USE-IT, an award-winning NGO

Advantages

Material Properties

- Cost effective
- Environmentally friendly: only 5% cement
- 10-20% more thermally efficient
- Estimate the money saved from landfill diversion costs will pay off equipment costs within one year.

Labor

- 10% reduction in construction time

Other

- Worked for Human Settlements & Infustructure in KwaZulu Natal to construct a 42m^3 low income housing unit

Disadvantages

- Require 5 day training course for operation of machinery
- 2 day trainig program to use machinery
- Brick making machinery is imported

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Selcrete

ALTERNATIVE BLOCK SYSTEM

Overview

- Wall blocks made by mixing cement, polystyrene, and Selcrete additive
  - Achieves lightweight low density block
- Building system compromises a mixture of Expanded Polystyrene (EPS) beads, cement and solution of water with liquid binding agent to form hollow blocks
- The blocks have a compressive strength of 7 MPa
- A 20 mm trement Polyvinyl Chloride (PCV) mesh is applied to external walls and finished off with plaster on both sides and painted
- Selcrete wall blocks laid in stretcher block method with mortar
- Selcrete products available in Guateng, Western Cape, and KZM

Advantages

Material Properties

- Blocks are light weight
- Selcrete has much higher R-value than clay brick and concrete
- 30 minute fire rating
- Fungi and bacteria resistant
- Can build up to 3 stories
- Selcrete 200mm thick walls deliverr a total R-value of 2.14m^2K/W
  - Good thermal properties/ helps keep building cool in hot climate

Labor

- Selcrete products can be stripped and erected within 48 hours of production
  - In situ surface beds and slabs can be walked on within 24 hours
- Manufactured on site, reducing manufacture and transport resources
  - It can be made from recycled material or pure material or both

Costs

- Costs on par with traditional materials but real cost saving is in ease of erection, acceleration of construction process, economics of scale

Perceptions

- Selcrete looks like traditional concrete blocks

Disadvantages

- Loadbearing structures are currently only approved to 3 stories
- Elcrete walls must be plastered and painted

Contact

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Shipping Containers

ALTERNATIVE BUILDING

Overview

- A steel frame shipping container is repurposed
- Steel dry cargo or aluminum shipping containers can be used
- Can come in sizes of 6 meters or 12 meters long
- Multiple shipping containers can be combined to create one house
- All units require insulation
- All internal plumbing and electrical work is done in a factory
- A concrete slab foundation is reccomended but not always necessary
- Units can either be finished to look like a container or can have a cladding system over it so it blends into any neighbourhood

Advantages

Material Properties

- Increased durability
  - Hurricane, earthquake, and torrando resistant
  - Can withstand winds up to 100 mph
- Eco-Friendly
  - re-uisng old shipping containers can reduce carbon footprint
- Easily transportable
- Pest and bug resistant
- Can last indefinitely

Disadvantages

- Does not provide jobs for a community
  - All work is completed in a factory
- People may have very negative perceptions
- Requires cranes to assemble containers
- Relatively expensive in comparison to BNG homes
- Currently build house by house not mass projects
- Need to prevent and treat any rust spots

Contact Info

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Trumod Modular Panels

STRUCTURALLY INSULATED PANEL

Overview

- Modular panels are used to create the framework of a house
  - Panels have 110mm polyurethane infill
- Modular panels are manufactured in Trumod factory according to strict tolerances, giving them consistent quality, making them highly accurate and preventing the risk of errors on site
- A concrete slab is used for a foundation
- Rails (often referred to as 'train tracks' are bolted to the concrete slab that the panels can slide onto
- The panels are bolted together
- Various roofing systems can be used to complete the design of the house

Advantages

Material Properties

- The walls are insulated
  - Thermally insulating
  - Acoustically insualting
- Easily transportable
- Tech is self-engineered
- Single and double story applications

Construction

- Precise Building
  - No waste on site
- Employs unskilled laborers
  - Very easy construction process
- Different form of foundation can be cost-effective
- Provide intial training services for laborers

Disadvantages

- Panels are manufactured in a factory reducing the opportunities to employ unskilled labor
- Trumod does not provide contracting services as they only focus on manufacturing and supply

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Constructon Experience

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UCO SolidWall

STRUCTURALLY INSULATED PANEL

Overview

- Made up of UCO Flexabord fibre cement sheets that are fixed onto steel studs and infilled with a lightweight concrete mix
- Solid, non-load bearing wall system
- UCO Flexabord is unsanded asbestos-free fibre reinforced cement board cememnt board with recessed edges
- Thickness of 6mm and 9mm, Length of 2400, 2700, and 3000mm, Width of 1200mm

Advantages

Material Properties

- Lightweight
- Quick to install
- Durable
- Water and fire resistant
- Acustic and thermal insulation

Labor

- Can be constructed easily and rapidly

Disadvantages

- No evidence of previous experience building low income housing

Contact

Supplier

- United Fibre Cement Company (UFCC)
  - Based in Cape Town
- http://www.ufcc.co.za/
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Additional Information

- UCO Flexbord PDF: http://www.ufcc.co.za/wp-content/uploads/2016/02/UCO-Vistabord-Brochure.pdf
- Brochure: https://www.zenithcpm.co.za/UCO%20SolidWall%20System%20-%20Brochure.pdf